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ABSTRACT

This report considers the potential for the use of the Australian Communications Satellite System (ACSS) for the Australian Schools of the Air (SOTAs) and the delivery of enhanced educational services, and develops the concept of all SOTAs operating through one transponder in a national beam. An evolutionary introduction of satellite transmission for teacher-to-student links and use of a combination of satellite, telephone, and HF transmission facilities for student-to-teacher links are specifically suggested. Cost estimates for various alternatives in implementing improved SOTAs are developed for comparative purposes. Discussion of enhanced educational services includes the identification of transmission facilities that could be provided through satellite links. In particular, the part-time use of the Homestead and Community Broadcasting Satellite Service (HACBSS) 30-watt transponder for broadcasting of educational television programs and of the 12-watt transponders for television distribution to schools is examined. Appendices include a calculation of the number of sound program channels of specified quality, a link analysis of student response channels, a link analysis for television transmission using a 12-watt transponder, a scenario for the evolutionary introduction of satellite communication links in the SOTAs, and estimates of transmission costs. (LMM)

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REPORT PREPARED FOR

THE COMMONWEALTH/STATE ADVISORY COMMITTEE ON THE EDUCATIONAL USE

OF

COMMUNICATIONS TECHNOLOGY

ON

POTENTIAL USE OF THE AUSTRALIAN SATELLITE COMMUNICATIONS SYSTEM FOR SCHOOL OF THE AIR AND ENHANCED EDUCATIONAL SERVICES

PREPARED BY

N.G. DAVIES AND J.A. GILLAM

The content of this report is the opinion and views of the authors based on material provided by the members of a sub-committee representing the educational authorities. The report is a working document intended to clarify the opportunities for educational applications of the Australian Communications Satellite System (ACSS) for use by members of the Advisory Committee and is not to be taken as representing the opinion or policy of the Department of Communications, the Departments of Education, AUSSAT Pty Ltd or Telecom Australia.

DEPARTMENT OF COMMUNICATIONS

CANBERRA

MARCH 1983

IR011230

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EXECUTIVE SUMMARY

The potential for the use of the Australian Communications Satellite System (ACSS) for educational services is explored in this report. Attention is focussed principally on Schools of the Air (SOTAs) as the educational and telecommunications requirements are well defined. The capability to deliver enhanced services is explored in some detail but less specifically.

In the SOTAs, the vagaries of the high frequency transmission medium and the very limited availability of additional channels are such that the organisation and operation of the SOTAs is severely constrained. Expenditures to improve existing student HF transceivers would yield marginal improvements in the reliability of the telecommunications links. The use of satellite links can provide more reliable communications (>99% reliability), of higher quality, with wider bandwidth and with availability of additional channels as needed.

Various satellite solutions based on the ACSS of AUSSAT are possible and considerable attention is given in the report to developing a concept of all SOTAs operating through one transponder in a national beam. Two satellite links need to be considered for the SOTAs: teacher-to-student and student-to-teacher links. For the teacher-to-student links, a 1.5 metre earth station designed for use in the Homestead and Community Broadcast Satellite Service (HACBSS) could receive highly reliable voice communications from a 12 watt transponder operating in the national beam. Sufficient capacity could be made available in one transponder to carry the current SOTA channel requirements and leave some capacity for growth.

Improvements for the student-to-teacher links using satellite channels can be achieved with earth stations at homesteads using antennas of 1.8 to 2.5 metres in diameter. It is possible to incorporate all links in one 12 watt tranponder for SOTAs all over Australia. Use of the telephone to link some students to the SOTA is attractive depending upon the distance from the SOTA and the availability of telephones. Use of the HF medium is also attractive in cases where students move or enrolment in a SOTA will be of short duration. In the report, an evolutionary introduction of satellite transmission for teacher-to-student links and use of a combination of satellite, telephone and HF transmission facilities for student-to-teacher links is suggested.

Cost estimates for a number of alternatives in implementing improved SOTAs are developed. These cost estimates are developed for comparative purposes only within the context of the report and are not intended to forecast the charges that operating agencies might make. Estimates of the annual costs of the satellite system are developed and compare favourably with other initiatives for remote area communications, although the estimated annual transmission costs are about an order of magnitude greater than those for the SOTAs as presently organised.

The evolutionary introductions of a satellite telecommunications system for the SOTAs as well as enhanced services is considered. A minimum start could be made in one SOTA with partial use of a transponder and taking advantage of potential loans of equipment and lease of transmission facilities.

Enhanced educational services are discussed with an identification of the transmission facilities that could be provided through satellite links. In particular the part-time use of the HACBSS 30 watt transponders for broadcasting of educational television programs and of the 12 watt transponders for television distribution to schools is examined. Specific scenarios and cost estimates can be developed using the material provided in this report when the required enhanced services are identified more clearly.

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PART A

1. Introduction and Background

In studies leading up to the decision to proceed with an Australian Communications Satellite System (ACSS), the potential of the satellite system to be used for educational purposes, in particular for the improvement of communications in the Schools of the Air (SOTAs), was considered to be very favourable. Following the decision to proceed with the ACSS, several meetings have been held between the Department of Education and the Department of Communications to examine more closely the potential use.

The Department of Education (DOE) has explored its interest in satellite communications largely through the Working Group on the Educational Use of Communications Satellites established in October 1979 by the Conference of Directors-General of Education. Assessments of the broad educational requirements of the States were developed but attempts to further the matter have been handicapped by lack of detailed substantive information on technical options for satellite transmission and information on the projected costs. Additionally, there was a need for better information on the potential for educational use of communications technology generally.

The Commonwealth Minister for Education formed an Advisory Committee on the Educational Use of Communications Technology to assess the latter subject. In October 1982 the Department of Communications (DOC) offered to make available specialised staff to co-ordinate the development, in co-operation with the educational authorities, of communication models using the ACSS, primarily in applications related to the SOTAs but also in applications related to enhanced educational services. The offer was accepted and a sub-committee of the Advisory Committee was formed with the following membership:

Mr Bob Rodgers	(DOE-WA) Convener
Mr John Kitt	(DOE-QLD)
Dr Norman Bowman	(DOE-NT)
Mr Colin Dunnett	(DOE-SA)
Mr Noel Haberecht	Commonwealth DOE
Mr George Davies	DOC
Mr John Gillam	DOC

The material of this report has been developed through meetings and discussions with members of the sub-committee. Specific data on educational requirements were provided by the educational representatives and through a visit by the authors to SOTAs at Charleville, Qld, and Katherine, NT, on 22-26 November.

The purpose of the co-operative study was to:

- obtain a clear understanding of the requirements of the SOTAs, with priority ratings;
- develop communications models to meet these requirements;

- rationalize the models with the requirements and develop a measure of cost/benefit;
- develop in detail one or at most two of the most promising models;
- make recommendations to the educational authorities on the most favourable option.

This report has been prepared to document the results of the study with the additional purpose to assemble sufficient detailed information to enable educational authorities to assess the opportunities.

In making assessments of the use of communications satellites, educational authorities are handicapped by inadequate knowledge of the potential to provide a specific service via satellites and the charges that would be made. It is very difficult to obtain this definitive data without an equally definitive statement of the requirement in telecommunications terms. It is time-consuming to do this for all the options which should be considered. Waiting for charges for specific services to be defined before any further work is done, however, is unrewarding and would mean that no progress could be made in developing the most promising educational services to be ready to use the ACSS at the time of the launch of the first satellite.

In this report, the technical aspects of particular service scenarios are developed in some detail. The costs are more difficult to derive and are discussed in Part B. Where charges are established (as for the use of terrestrial links) or have been given as a guide in public meetings (as for the satellite transponders), these are used. Where the charges are not known, the implementation is hypothetical and charges are therefore even less definite, the approach used here is to develop consistent estimates of costs. These costs are certainly not charges and are intended for use only in the context of this report to examine trade-offs between services by assessing potential benefits of a given service scenario in relation to self-consistent estimates of the transmission costs. The unit of measure of cost should be taken as "counting units", with the symbol $, with dollars convertible to counting units but not the reverse.

If, after assessment, one or two service scenarios are judged to be worthy of development in detail for potential implementation, the desired configuration and the charges will have to be discussed and negotiated in specific detail in consultation and co-operation with AUSSAT and Telecom Australia.

The material of this report is the opinion and views of the authors with interpretations of material and comments provided by members of the sub-committee representing the respective educational authorities. The report is a working document intended to clarify the opportunities for the educational uses of the ACSS for use by members of the Advisory Committee and is not to be taken as a formal document representing the opinion of DOC or the respective DOEs.

2. Schools of the Air

2.1 Requirements

Basic SOTA

The State educational representatives on the sub-committee provided detailed information on the organisation and operation of the SOTAs. Table 2.1-1 tabulates the channel requirements of the SOTAs as now constituted using HF communications links. These 1983 projected figures are only one basis for planning. They reflect the present role of the SOTAs, not as they might be under different transmission scenarios.

The operation of the SOTAs is based upon communications criteria originally developed for the Royal Flying Doctor Service (RFDS) using high frequency (HF) radio which, at the time it was implemented, was the only medium which could provide communications over the large areas involved. The concept of the RFDS communications is to provide a radio link to alert the medical service to an emergency. Transmissions are intended to be infrequent and of short duration covering people at homesteads and on field parties. Most recently, the networks have also been used to send and receive telegrams and to provide a radio-telephone extension to the Telcom network.

Basic elements of RFDS communications are the transceivers, the "Flying" Doctors and the homestead medical kit dispensed by a paramedic. The SOTA has adopted a parallel system for reasons no doubt based on:

(a) the nature of the HF transmission and the "press-to-talk" simplex audio channel equipment involved;

(b) the geographically dispersed nature of the client population;

(c) the priority and resources allocated to the services.

The parallelism between the RFDS and the SOTA services is illustrated in Table 2.1-2.

Table 2.1-2 Service Delivery Concepts

	MEDICAL SERVICE	EDUCATIONAL SERVICES
On-site arrangements	Homestead medical kit Paramedic	Correspondence School kit Home tutor
Professional expertise	Flying Doctor	SOTA teacher and visiting teachers
Radio link	HF transceiver	HF transceiver

TABLE 2.1-1

SCHOOLS OF THE AIR

(1983 PROJECTED FIGURES)

STATE	PLACE	SUBSCRIBER SETS (c)	RADIO CHANNELS (a)	NUMBER OF SIMULTANEOUS CLASSES	HOURS OF OPERATION (LOCAL TIME (b)
Western Australia	Derby	26	1	1	0800-1600
	Port Hedland	18	1	1	0800-1600
	Carnarvon	35	1	1	0800-1530
	Meekatharra	40	2	1	0800-1530
	Kalgoorlie	32	1	1	0800-1530
Northern Territory	Katherine	105	4	1	0700-1600
	Alice Springs	70	2	2	0700-1600
Queensland	Charleville	240	4	4	0830-1530
	Cairns	130	3	3	0830-1530
	Mt. Isa	100	2	1	
South Australia	Port Augusta	65	2	1	0800-1600
New South Wales	Broken Hill	89	2	1	0900-1530
TOTALS	12	950	-	18	

NOTES

a) Incorporates dedicated SOTA channels and those RFDS or other channels accessed by SOTA.

b) Monday to Friday only shown. Some transmissions also on Saturday and Sunday mornings.

c) Total enrolment is approximately 2000 students.

In the present arrangement, a SOTA class typically is half an hour in duration and consists of a teacher and some 8 to 15 students. The teacher leads a class discussion which is focussed on an aspect of correspondence school lessons. There is a very active verbal exchange with the objective to involve each student and to provide experience in social interaction. A great effort is made to schedule one class per day per student.

The class session is frequently compromised by the HF medium due to either occasional complete failure of the teacher-to-student links or the poor quality and the frequent fade-out during the class of signals from students. Due to the poor sound quality, rather intense concentration is required of the teacher and students. This is one factor which determines the half hour duration of a class period. Another factor is the great difficulty of obtaining additional useable frequency allocations. This restricts the number of classes that can be run concurrently and therefore the number of sessions that can be fitted into each day.

The nature of the SOTA service has evolved over the past decade. A significant step came with the merger of primary correspondence and radio schools at the Katherine SOTA in 1973. Such a merger has been implemented also at the Alice Springs SOTA and is now under close study in the states of Queensland and Western Australia.

Existing SOTA class organisation is dependent upon two variables:

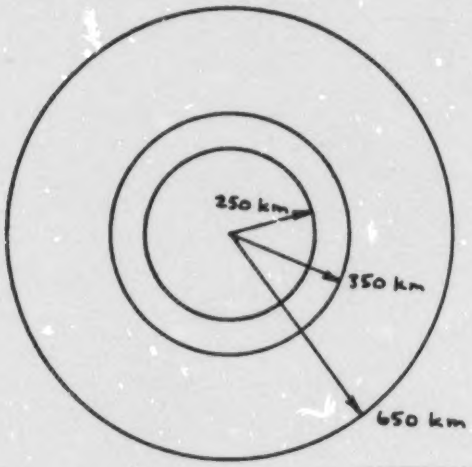
(1) coverage area of reliable transmissions;

(2) number of students in each class.

The trend has been for SOTAs operating in difficult transmission areas, or where interference is particularly strong (eg the tropical areas), to transmit the same lesson on as many available frequencies as possible in the hope that the teacher's signal will be audible to all students. This may be termed "Saturation Coverage". The technique is used, for example, by the Katherine and Alice Springs SOTAs.

The main alternative to "Saturation Coverage" is "Concentric Circle Coverage" illustrated in Figure 2.1-1 whereby a frequency is allocated to a circular zone defined by the radial distances from the teacher's transmitter. Within each concentric zone a full range of classes from Years 1 to 7 is taught. The technique is utilised, for example by the Charleville and Cairns SOTAs.

Figure 2.1-1 Indicative Concentric Circle Coverage Areas



One of the main difficulties with both the Saturation and Concentric Circle Coverage models is that only students living nearby can hear the responses of a student to the teacher. Consequently, it has been long argued that any improvement to a basic SOTA service should at least enable all students participating in a class to hear each other. Because the teacher and students all operate on the same frequencies, a student's response cannot be relayed by the more powerful transmitter of the teacher. Also the poor quality of these signals would make it of doubtful value.

The services provided by the SOTAs are augmented currently by a video scheme funded by the Commonwealth Government. Known as the Loan Video Program, it involves the nation-wide capital expenditure of $4 million over three years to provide video-cassette recorder/players and monitors for use in the isolated homes where children who are enrolled in a SOTA live. The scheme is designed mainly to use a selection of programs from the ABC schools telecasts of about 3 hrs/fortnight. Each State educational authority is responsible for assembling and distributing this and other material which they may choose to incorporate and for maintaining the equipment.

Educational objectives which underlie requests for the improvement of existing SOTA facilities include:

(1) capability for the teacher to be heard clearly by all students;

(2) increased flexibility in the allocation of students to classes within the limits of studio capabilities;

(3) introduction of capabilities for each student in a class to hear all other students;

(4) introduction of a range of narrow-band communications facilities beyond two-way voice, particularly on the teacher-to-student link. Applications for such a facility include:

- simple computer-aided instruction packages;
- several pages of text in electronic files;
- computer programming instruction.

The possibilities of augmenting the services for the Primary as well as the Secondary Correspondence Schools would make it necessary to conduct more classes simultaneously and perhaps to originate programs from additional locations. This would lead to a requirement for an increased number of communications channels to handle a greater number of subjects as well as more classes at each year level.

Enhanced Services

Consideration has been given by educational authorities to incorporating the present SOTA service into a more comprehensive distance education delivery package. It needs to be stressed that decisions on such a package are to be determined by educational authorities. Factors influencing such decisions will be:

(1) general policies in relation to the expansion of education services for remote and isolated students;

(2) availability of funding;

(3) awareness by educational authorities of communications technologies;

(4) total and comparative costs of terrestrial and satellite communications links.

Given these factors, enhanced services such as radio and television educational broadcasts might use the direct broadcasting facility of the AUSSAT communications satellites. Other opportunities involving interactive television and two-way audio links need to be examined.

The State educational authorities have provided to the Commonwealth Department of Education appreciations of the potential requirement for services that could be provided by the satellite. These are summarized in Table 2.1-2. Enhanced services are discussed in more detail in the following sections.

TABLE 2.1-2

STATE ADDITIONAL PLANNING/LONGER TERM OBJECTIVES AS PROVIDED IN SATELLITE PLANNING DOCUMENTS FORWARDED TO THE FEDERAL DOE

Western Australia:

Educational TV broadcast 3h/d; 5d/w at least
During day: Support SOTA, Isolated Student's Matriculation Scheme, small rural schools.
Evening: Support Technical and Further Education (TAFE), community education programs.
Midnight-dawn: Transmit pre-recorded television and films for recording by users.
(Videotape productions to 250 schools and to students in 120 isolated locations at present).

Northern Territory:

An overall priority requirement is for a reliable, continuous and private telephone network.
Video programs transmitted during off-peak times.
Secondary Correspondence School could become Secondary SOTA as could TAFE and Darwin Community College.

Queensland:

First priority is technically superior two-way audio teaching with maintenance of the decentralised SOTA. SOTAs now serve 430 families and this is expected to rise to 660, maximum, with satellite service. The introduction of satellite services must be evolutionary.

Would like to address commencing a service of direct broadcast television to SOTA students (a direct extension to Loan Video Scheme) of about 1h/d, 5d/w.

In addition, delivery of film material now available to schools, colleges and individual learners for recording for later use would be desirable; about 1h/d, 5d/w.

South Australia:

SOTA evolution to multi-channel Schools Broadcasting Unit with two-way audio and one-way video would be attractive. Initial use of 5 circuits by SOTA might grow to 10 within 5 years. The system would also be used by the Correspondence School which would merge with the SOTA. There is a perceived need to provide secondary education of a wide diversity to small and remote schools requiring 6-12 additional audio circuits and video on some occasions. Audio circuits will also be required for co-ordination purposes.

New South Wales:

No input yet received.

Victoria:

Identifies desirability of an educational TV channel.

Tasmania:

No input yet received.

Australian Capital Territory

Could provide special interest educational TV material about 2h/w.

2.2 Satellite Service Scenarios

There are essentially two service scenarios for the provision of educational services. These are:

(a) Basic SOTA services with upgraded transmission using:

- HF radio;
- Telecom telephone links;
- satellite voice links;
- a combination of these.

(b) Enhanced services using:

- highly reliable audio links for SOTAs;
- television transmission to isolated individual students and schools;
- interactive television in the form of extended classrooms with audio participation by individual students or by groups of students in isolated schools;
- reliable audio conference links for educational or administrative purposes;
- reliable audio links for data transmission for purposes of information access, transfer of pages of text, interactive access to files, message transmission and computer applications.

The SOTAs were selected for particular examination as the requirement for the service is defined and the infrastructure to provide the service exists. The HF transmission medium severely constrains the service as previously discussed. Satellite communications has the potential to overcome many of the transmission contraints. The next section contains a development of a number of alternative transmission scenarios. Figures 2.2-1 and 2.2-2 illustrate the basic SOTA with upgraded transmission facilities.

The consideration of enhanced educational services is much more difficult, although it is in this area that greater rewards of satellite communications for educational purposes could well be achieved. The basic organisations that could produce several hours per day of educational television are not defined, and there is no unanimity that this is a rewarding route to follow. The Loan Video Program is providing some data but more experience is needed to determine the role of television. The same applies to a greater or lesser extent to the other enhanced services. Figure 2.2-3 illustrates the potential implementation of satellite communications for enhanced educational services.

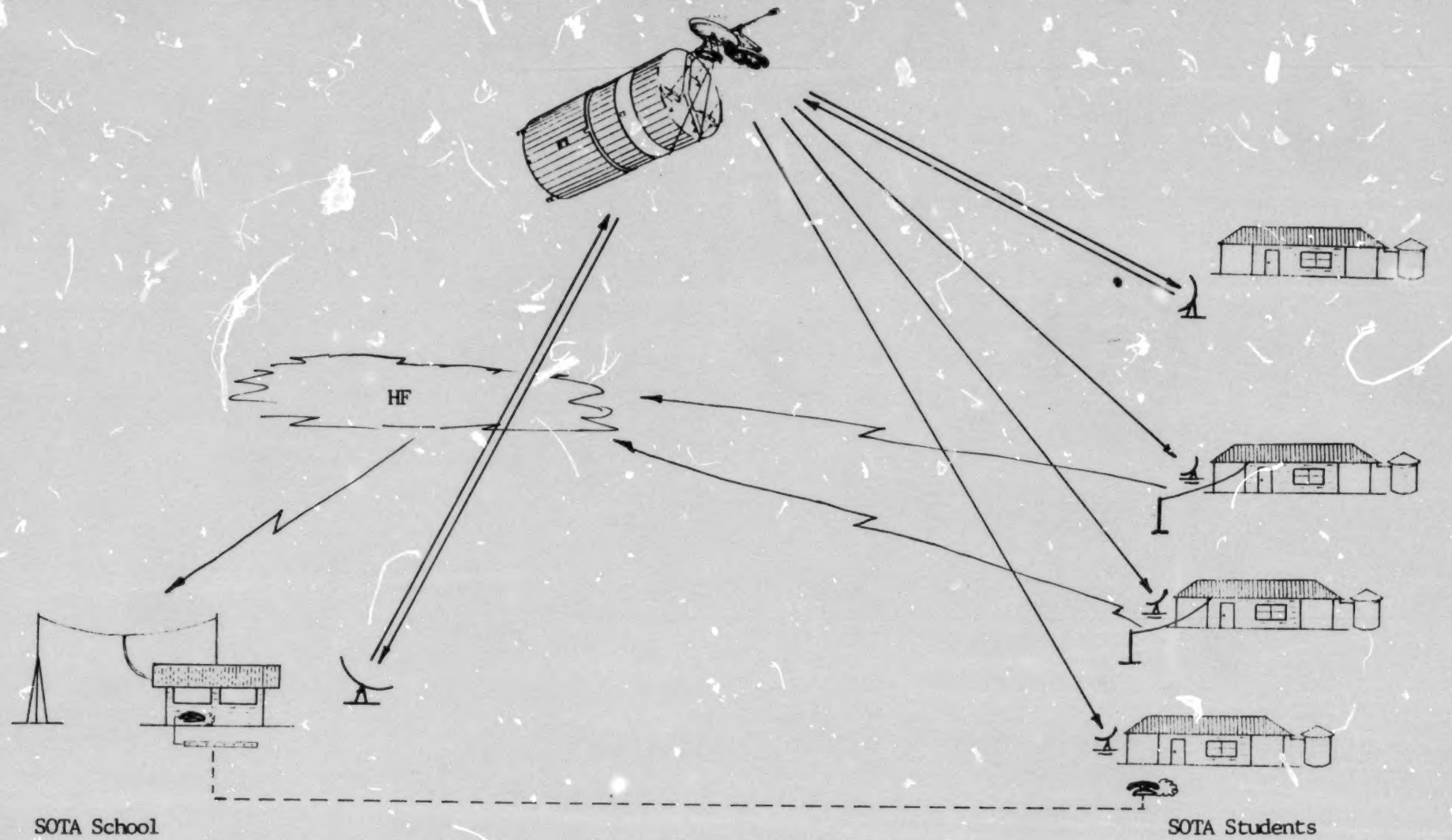
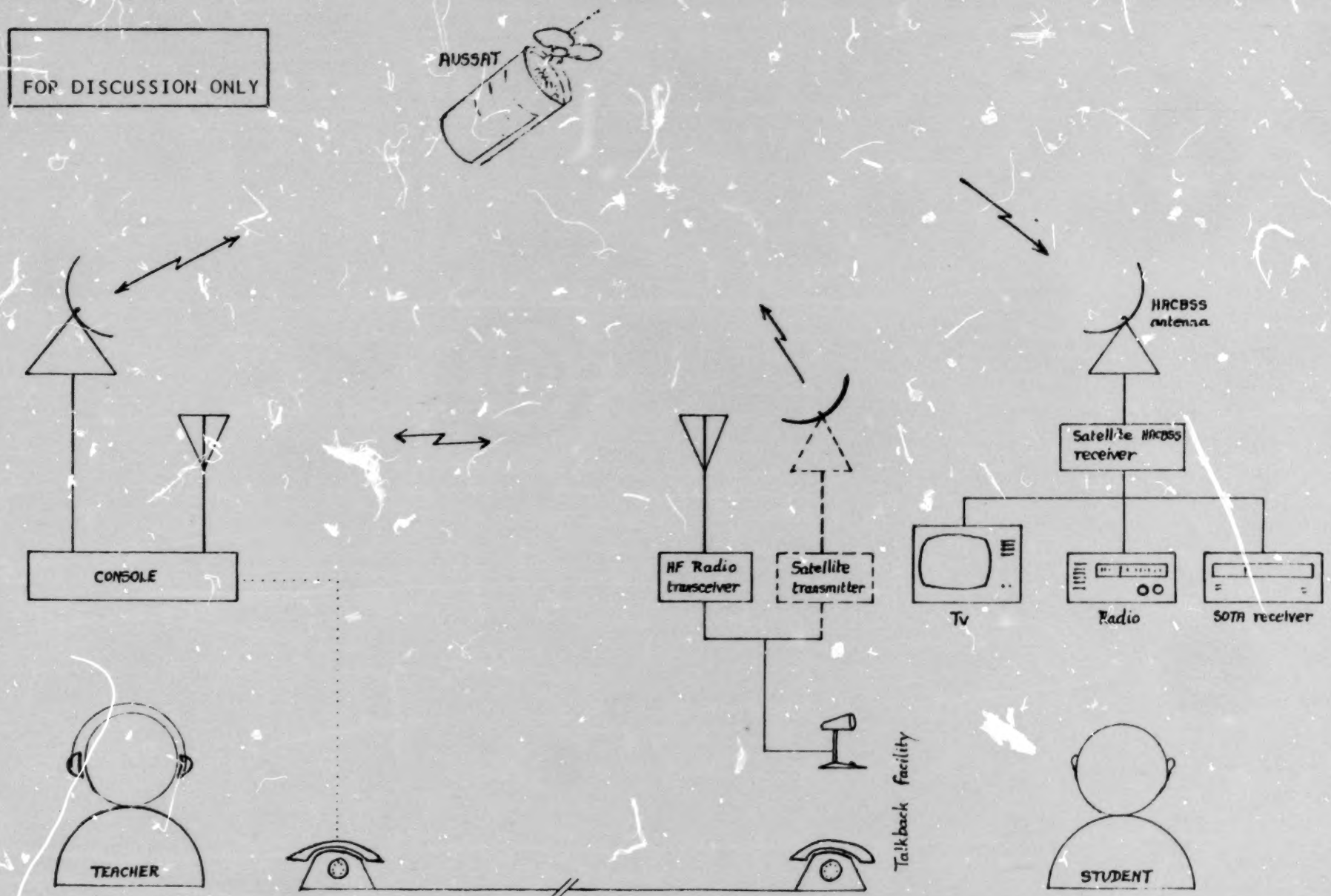


Figure 2.2 - 1 Basic SOTA With Upgraded Transmission



19 Possible Technical Options for Satellite-Based School-Of-The-Air (SOTA) Services 20

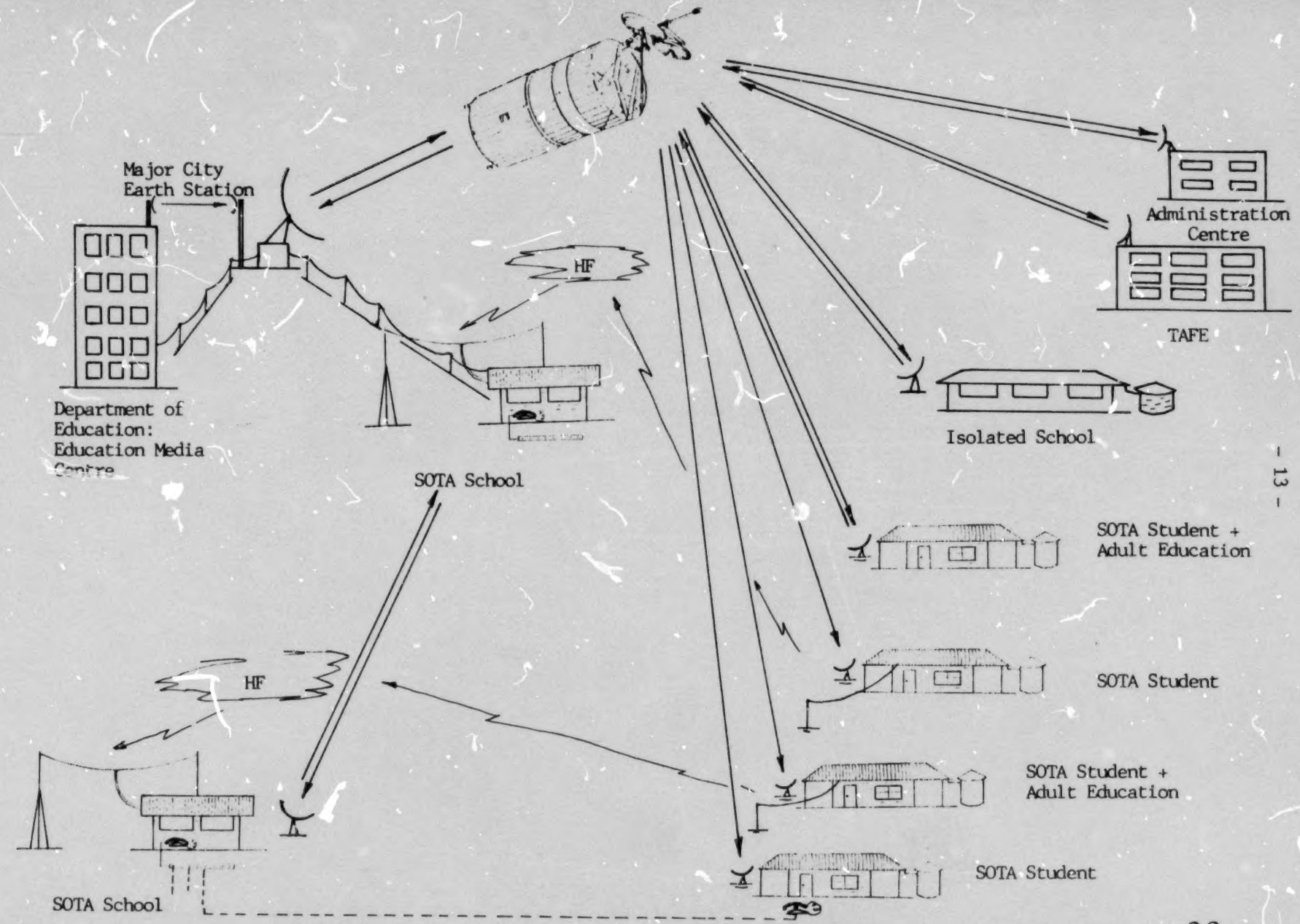


Figure 2.2-3 - Enhanced Educational Services

2.3 Technical Aspects

The ACSS will consist initially of two active satellites each of which will have eleven 12 watt transponders and four 30 watt transponders. Communications signals transmitted to the satellite from earth stations (uplink stations) are amplified and retransmitted by the individual transponders in the satellite to receiving earth stations (downlink stations). The satellite receives signals in the frequency band 14.00-14.50 GHz and transmits them in the frequency band 12.25-12.75 GHz. Each of the transponders operates in a different fraction of the uplink and downlink bands.

The individual transponders can be connected to radiate a signal which covers either all of Australia or certain of four separate zones. Figures 2.3-1 and 2.3-2 show the national and zonal coverage. On the figures is shown the signal powers that are radiated. The larger signal powers can be received with smaller antennas (and vice versa).

The 30 watt transponders are designed principally to operate in the zonal beams to broadcast television and radio programs to small low cost receive-only earth stations in the Homestead and Community Broadcasting Satellite Service (HACBSS). The HACBSS-1 will provide a regional ABC television service and two or three ABC radio programs to each of the zones. The proposed HACBSS-2 could provide some form of commercial or other alternative television and radio programs. The 30 watt transmit power plus the concentrated zonal beam will permit individuals to receive signals with earth stations having antennas of 1.2 to 1.5m diameter and costing about $1,000. Figure 2.3-3 shows an example of one of these earth stations. The 30 watt transponders are also switchable into the national beams and may, as an alternative to the HACBSS-2, be used to provide program distribution to more costly earth stations having larger antennas of 3 to 8m diameter.

The 12 watt transponders are designed principally to provide for the distribution of television and radio programs (a point-to-multipoint service), and trunk telephone and data signals between identified locations (a point-to-point service) using the portion of the frequency band assigned for the Fixed Satellite Service (FSS). The main distinction between the broadcasting and the fixed services is whether the intention is for reception by members of the general public (HACBSS) or for private communications between identified parties or locations (FSS).

Out of the many possible uses of the 30 watt and 12 watt transponders for telecommunications, the uses for educational applications are the broadcasting or distribution of television or audio programs, the provision of television and/or audio links for participation by isolated students and schools in extended classes and the provision of narrowband voice channels, or the equivalent, which can be used for verbal interaction or for data or facsimilie transmission for education-related activities.

Figure 2.3-1 - 12 Watt National Coverage

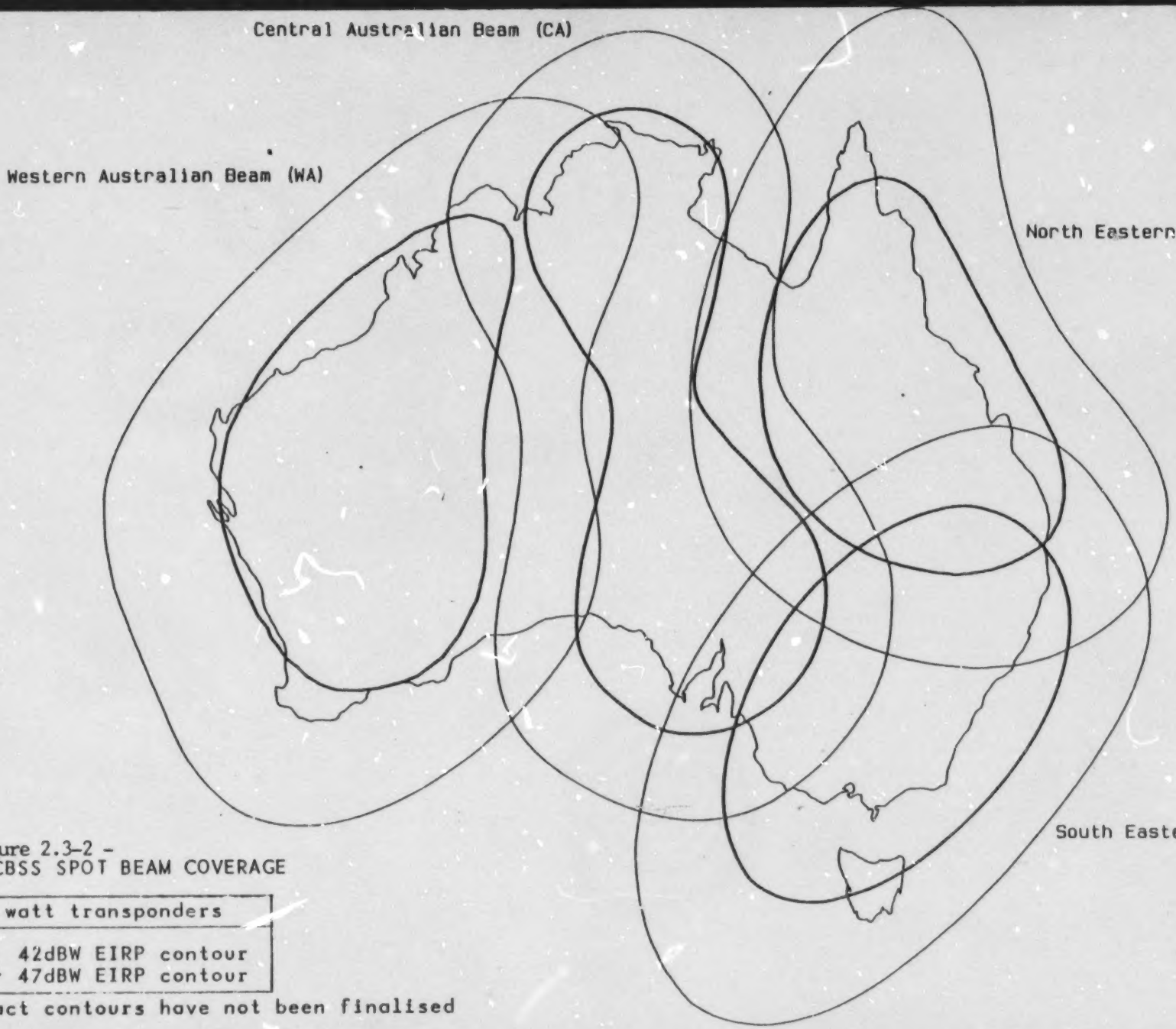


Figure 2.3-2 -
HACBSS SPOT BEAM COVERAGE

30 watt transponders

— 42dBW EIRP contour
— 47dBW EIRP contour

Exact contours have not been finalised

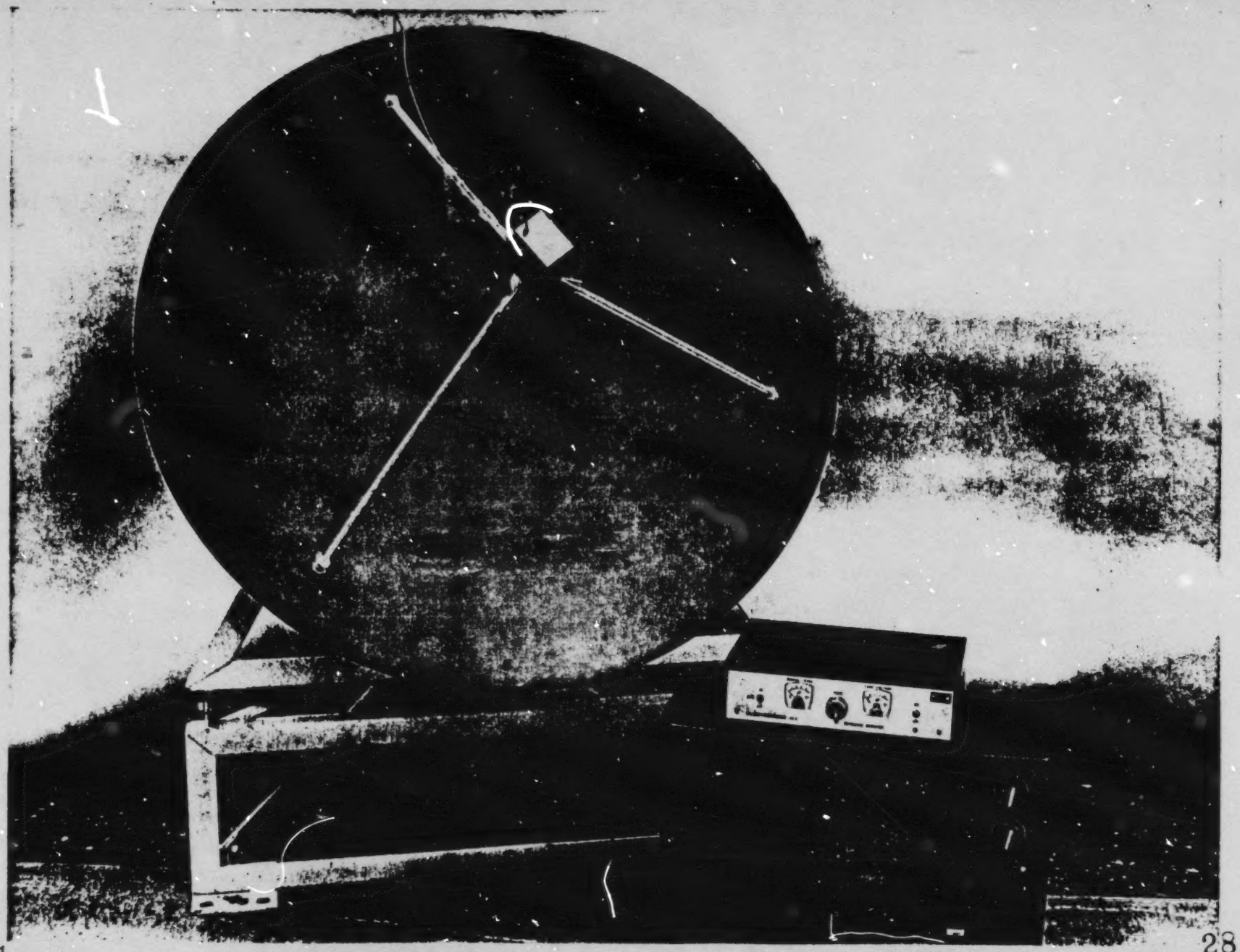


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Figure 2.3-3 - An Example of a Commercial 1.2m TV Receive Terminal

As explained in the previous section, the applications of satellite communications which are considered in detail in this report are those related to the SOTAs. As the operational requirement is reasonably clear, specific answers can be developed. It is more difficult to select from among the many other educational enhanced services those that are worth pursuing. The operational requirement and mode of the service are much less clear. The use of satellite links for educational purposes related to the SOTAs and to some enhanced educational services are the following:

(a) Part-time use of HACBSS or 12 watt channels for educational television for immediate use or for video tape recording for use later.

(b) Use of audio channels in 12 watt transponders in zonal or national beams for teacher-to-student links.

(c) Use of voice channels in 12 watt transponders in zonal or national beams for student-to-teacher links.

(d) Use of the above links individually or in combination for enhanced services.

The technical aspects of each of these scenarios are developed in the following sections. Comparative cost projections are developed in Part B.

2.3.1 Use of HACBSS or 12 watt Transponders for Educational Television

As discussed previously, the 30 watt transponders are designed to broadcast a television and associated audio signals for reception by earth stations with 1.2 to 1.5m antennas. The quality of the signal will be roughly equivalent to that received by individuals off-air from a broadcast transmitter or provided by a well adjusted video cassette recorder (VCR). A higher quality signal suitable for retransmission or distribution by cable throughout a school or a building housing an administrative organisation could be provided by using a larger antenna.

It is anticipated that the program material for this transmission could be taped programs, live interviews, discussions, demonstrations of concepts and classroom sessions each of which might be suitable for regular school classes, adult education or special interest education (eg trade skills).

In some cases, it could be desirable to provide a response channel in order that a group of students in a school or an individual student at his home could interrupt a class session to obtain clarification or otherwise participate. This could be provided by HF radio, a telephone call or by a voice response channel over the satellite (see Section 2.3.3).

The requirement and the amount of programming available for educational television would not justify the full-time lease of a transponder. In order to broadcast programs to individuals by means of a HACBSS transponder. Arrangements would have to be made to share use of one of these with either the ABC or a commercial television service. This would likely preclude operation in the prime time evening hours, when there would be the largest audiences for entertainment programs, although this would be the most suitable time for adult education. Periods between the hours 0900-1600 could be available for real-time programs and between the hours from approximately midnight to 0900 for transmission of programs to be taped for future use.

The 12 watt transponders are too low in power to be used for television broadcasting but can be used effectively to distribute television programs to larger earth stations at schools or administrative centres. Such use of 12 watt transponders would have some attraction if the SOTA educational services were provided through a 12 watt transponder, and use of such a transponder were time-shared between the different educational services.

Appendix 3 contains an analysis of a television link using 12 watt transponders. It is shown that a 3.0 to 5.2m antenna for an earth station (the size depending upon the geographic location) would be required to receive HACBSS quality television in the national beam. If the 12 watt transponder were switched to a zonal beam (there are contraints on which zones), a smaller antenna of 1.6 to 2.6m would be required to receive the signal.

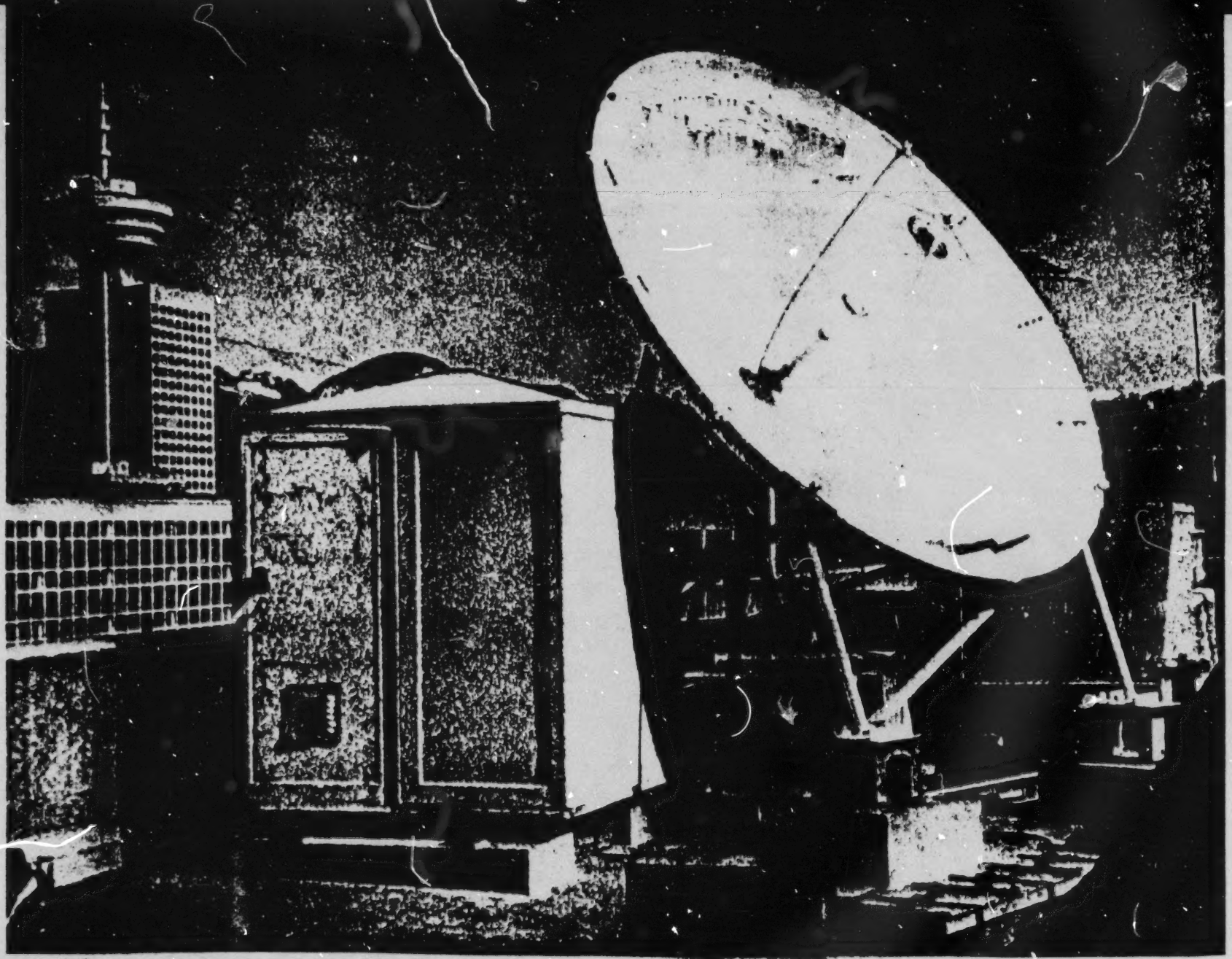
The uplink for educational television could be through AUSSAT's major city earth stations with terrestrial interconnections to the educational institutions or through dedicated special purpose uplinks at the institutions. Figure 2.3-4 illustrates such a user-owned uplink.

2.3.2 Use of Audio Channels in 12 Watt Transponders for Teacher-to-Student Links in SOTAs

Although the teacher-to-student links provided by HF radio are of quite good quality, a satellite link would be much more reliable and would have transmission characteristics that would support data transmission and facsimile which might be required for enhanced services.

In this section, use by students of a HACBSS earth station with a 1.5m antenna will be assumed to receive the SOTA audio channel to provide the cheapest possible implementation.

Appendix 1 contains detailed link calculations to establish the number of teacher-student links with a range of characteristics that could be provided by one 12 watt transponder to 1.5m HACBSS type earth stations. The individual SOTA transmissions would be



31

Figure 2.3-4 - An Example of a User Owned Television Uplink

32

single-channel-per-carrier (SCPC) with multiple carriers in one transponder. For purposes of the calculation, frequency modulation is assumed as this is widely adopted and hence a wide variety of equipment is available to choose from. There could be advantages in the use of a digital form of modulation, although it is less well developed at this time. There would not be a large change in the number of links. Digital modulation should be examined at a more detailed stage of the design. Table 2.3.1 summarizes the results.

Table 2.3-1 - Number of Simultaneous* SCPC Teacher-Student Links Using 1.5m HACBSS Receive Terminals

Quality of Link	12W Zonal Beam		12W National Beam	
	No Compander	Compander	No Compander	Compander
15kHz bandwidth with HACBSS program quality	12	-	3	-
8kHz bandwidth with quality equivalent to TV sound	14	18	4	7
5kHz bandwidth with quality equivalent to AM radio	20	29	7	12
3kHz bandwidth with good telephone quality		142		35

* Continuous transmissions.

Examination of this table indicates that use of the 12 watt transponders in zonal beams would provide more than the number of channels required by the SOTAs in each zone (see Table 2.1-1). However, this would require partial use of four transponders, with the resultant technical inefficiencies for AUSSAT and cost implications for the DOEs. It would be much more economical if the needs of all the SOTAs could be met through combined use of a single transponder operating in a national beam. The total number of simultaneous channels presently required (from Table 2.1-1) is 18 and there should be some potential for growth. Examination of table 2.3-1 indicates that only use of telephone quality channels would meet the requirement. However, having narrowed the choice down to this area a number of further aspects can be explored as follows:

(a) Using a 5kHz bandwidth, the quality of AM radio, with voice activation (activating the transmitter only when someone is speaking as employed in satellite telephony systems) and assuming an activity factor for the teacher's speech of perhaps 70% (the factor for normal telephone conversation is 40%) and a utilization factor of 70% for individual SOTA links, could result in up to 20 links.

(b) Reducing the design specifications for the audio quality of the 5 kHz bandwidth could increase this number to about 30 links.

(c) The number of telephone quality channels could be increased to 71 by introducing the factors in (a).

(d) Increasing the size of the students' earth station antennas from 1.5m to 2.4m would approximately double the number of channels.

Introduction of these improvements (a) to (c) would raise the cost of the addition of a demodulator to the basic HACBSS earth station to perhaps $400 leading to a total earth station cost of $1,400. A larger antenna could increase the cost to about $2,000.

It must be concluded that use of a 12 watt transponder in a national beam is workable. This is likely to be cheaper than use of zonal beams, by a wide margin. This is the only option that will be considered in more detail.

Figure 2.3-5 illustrates the choice between use of a major city earth station or a dedicated SOTA-owned earth station for the teacher uplink. Figure 2.3-6 shows a possible 3m SOTA audio uplink/downlink earth station.

There is one technical complexity which should not be forgotten. HACBSS television and sound programs will be transmitted to four zones with two different polarizations from two different satellites. The configuration will be determined when AUSSAT assigns transponders to particular services. SOTA or other educational programs transmitted in a national beam would be received from one satellite with one polarisation (as determined by the assignment of HACBSS and SOTA transponders). HACBSS earth stations in one of the zones could receive SOTA signals by tuning to the SOTA transponder. In another zone, to receive the SOTA signals, the polarization of the HACBSS receiving antenna feed would have to be rotated or switched. In the other two zones, to receive the SOTA signals, the HACBSS antenna would have to be swung to point towards the other satellite with some adjustment or switching of the polarization. Because of these factors, it could well be cost effective to have a separate earth station at many student homesteads to receive SOTA signals, in addition to the one owned by the family to receive HACBSS signals. This is the assumption made in the costing estimates in Part B.

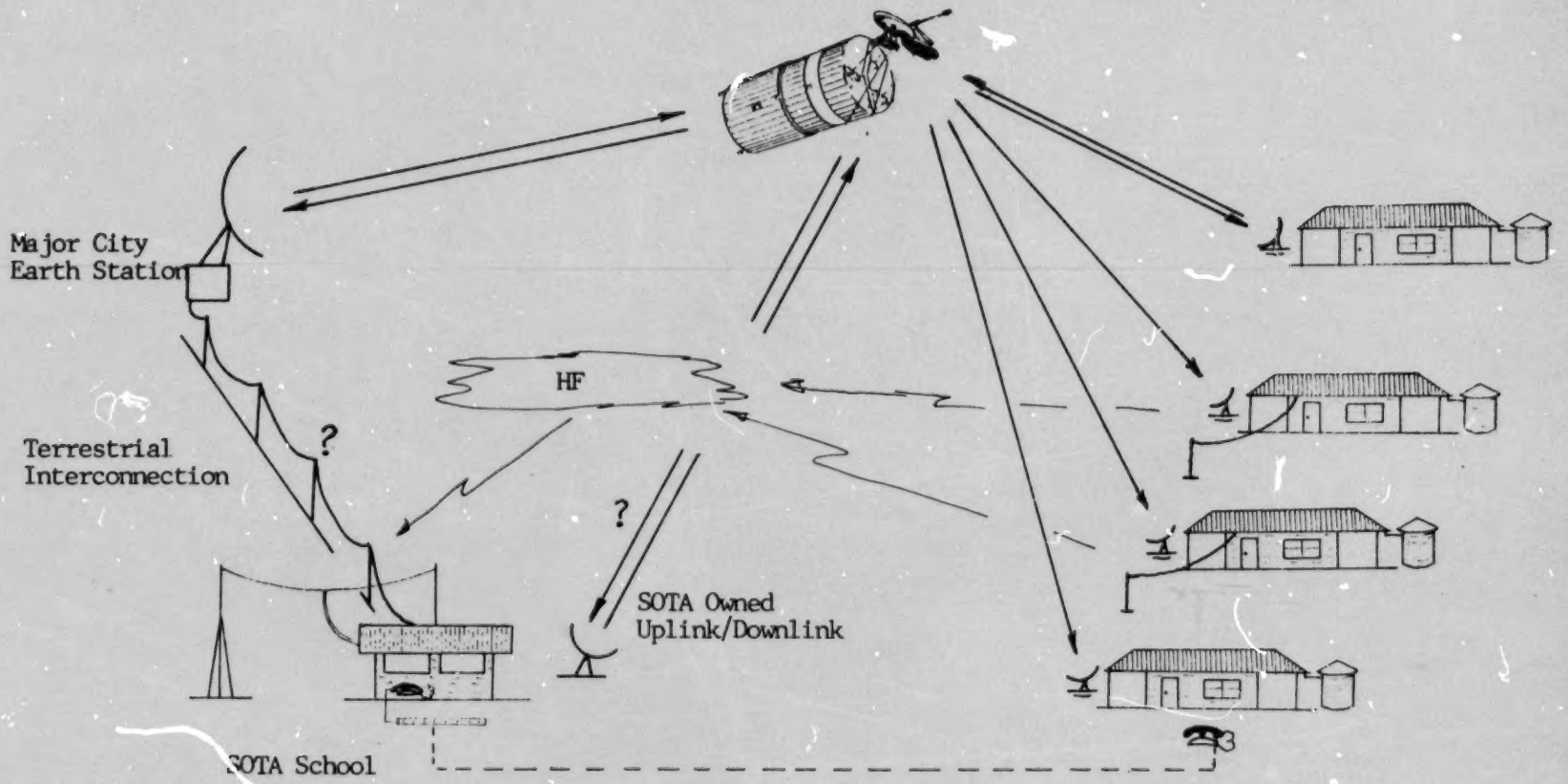
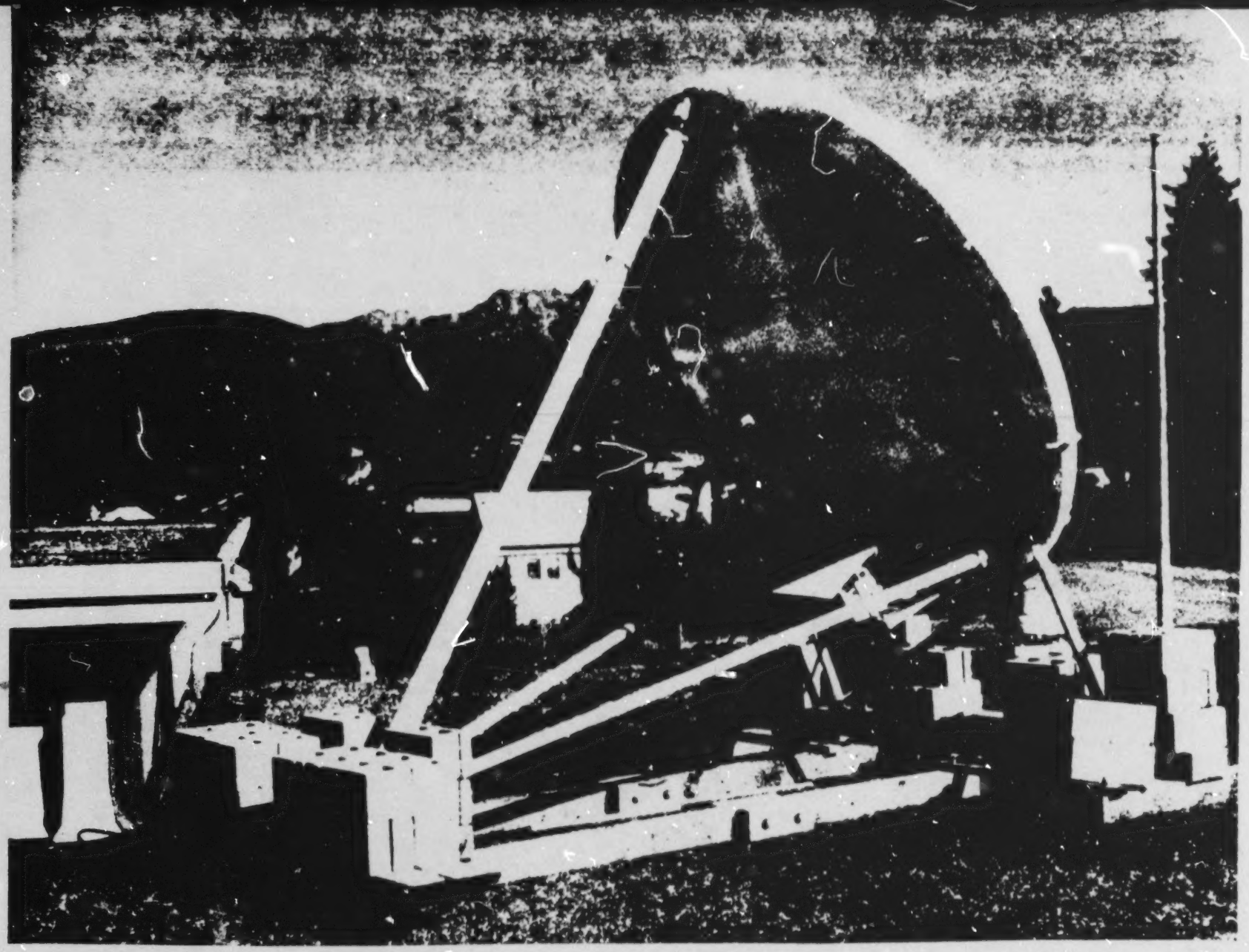


Figure 2.3-5 - Use of Major City Earth Station or SOTA-Owned Uplink/Downlink



37 Figure 2.3-6 - An example of a Possible SOTA Audio Uplink/Downlink Station 38

2.3.3 Use of Voice Channels in 12W Transponders for Student-to-Teacher Links

The link from the student to the teacher is the more difficult to improve using the satellite because student uplink transmitters are much more expensive than the downlink receivers. This is due to the accuracy required for the transmit frequency, the high cost of the transmitter power amplifier and the size of antenna required both to access the satellite and to reduce the interference to adjacent satellites to an acceptable level.

AUSSAT have specified a "minor earth station" for procurement that would have suitable characteristics. Basically, this is a telephony terminal without the telephone interface equipment. It would typically have a 2.5m antenna, and a 1 watt solid state power amplifier, although antennas as small as 1.8m could be feasible for specific applications. Considerable work is underway in companies in many countries to develop low cost telephony earth stations. In 1975, these earth stations cost $100,000 each. In January 1983 the press reported signing by AUSSAT of contracts totalling $1m with three suppliers for a total of 21 minor earth stations to be delivered in 1985. This indicates an average unit cost of about $50,000. There are confident projections that the cost will be reduced to $25,000 in quantities of 100 (well within an empirical costing rule that increasing production by a factor of 10 halves the per-unit cost). For SOTA applications, it could be possible to utilize the HACBSS receiving electronics to replace the receiving portion of the terminal resulting in a further reduction of the cost to perhaps $10,000-$15,000. Figure 2.3-7 shows a prototype of a 1.8m earth station that might be suitable for use by SOTA students. It is very difficult to hypothesize a lower cost before 1990 at which time the market size will be more certain and entrepreneurial innovations could have had an impact.

The use of these uplink earth stations would be for individual students to respond to the teachers. Students in a class in any given SOTA that are equipped with an uplink earth station would share a voice channel. Individual access would be push-to-talk or possibly voice activation.

A number of student-to-teacher channels at least equal to the number of SOTA classes, or teacher-to-student channels, would be required. The student transmissions could either be linked back to the SOTA through a major city earth station with terrestrial interconnections or directly to the SOTA by equipping the SOTA with a suitably large receiving earth station (one with a 4m diameter antenna). The latter is almost certainly the more economical to avoid the cost of the interconnecting terrestrial links. The skill level for reception at a SOTA is much less than that which would be required to manage a SOTA uplink earth station. This presents no difficulties.

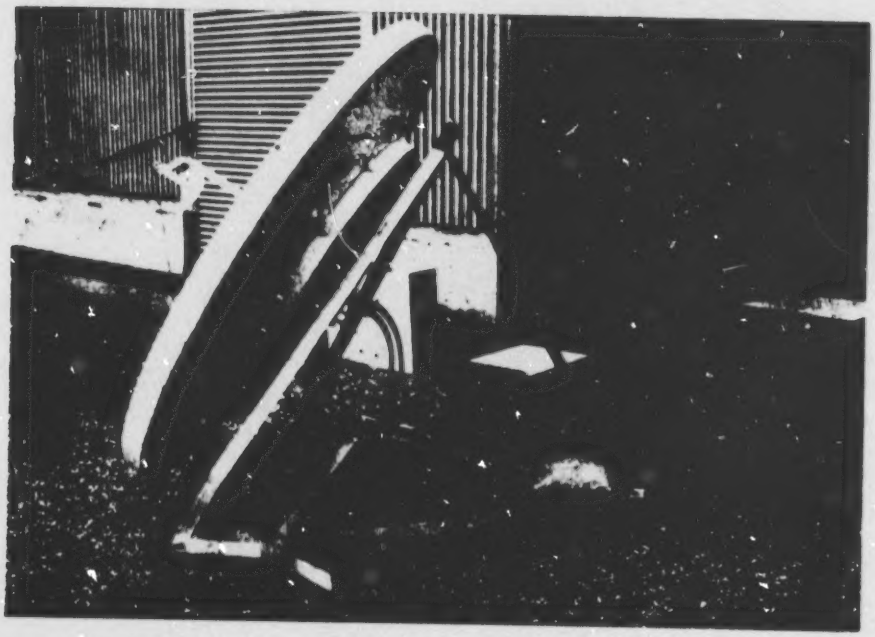


Figure 2.3-7 - A 1.8m Uplink/Downlink Voice Earth Station

The previous section contains an analysis of the number of channels that could be supported for several different bandwidths of the teacher-to-student links. The trade-off between signal quality and transmission capacity was examined. These links are identified as teacher-to-student audio links. For the student-to-teacher return links it is important to minimize the cost of the student transmitting earth stations. This minimization occurs for the lowest channel bandwidth. Hence only 3 kHz telephone voice quality channels are considered. These are designated as student-to-teacher voice links.

Appendix 2 contains an analysis of the communications links for the student uplinks and for major city or SOTA downlinks which shows the basic feasibility of the use of an earth station at the students' homesteads with either a 1.8m or 2.5m antenna. The difference between these two earth stations is not so much the cost of the antenna as the difficulty and associated cost of transporting and installing the earth station on a homestead. The latter is very much lower for a 1.8m than for a 2.5m antenna.

The amount of transponder power required for the links is estimated in the Appendix as 2%-6% of the total transponder power. Therefore it would be quite practical to accommodate these links within the same transponder as used for the teacher-to-student links. A very careful design would be required to establish exactly the sharing of the transponders and the optimization between the size of the antennas for the student earth stations and for the SOTA receiving stations or the use of major city earth stations. Figure 2.3-8 illustrates the shared use of a 12 watt transponder operating in a national beam.

It is recognised that the cost of installing a transmitting earth station at the homestead of a student is high. To contemplate installing earth stations to replace all the HF sets used by the SOTAs, approximately 950, would result in a greater utilisation of such earth stations than for any other presently planned purpose. It appears therefore to be unrealistic to propose satellite uplinks at each homestead. For purposes of analysis, use of a total of 100 student uplink earth stations will be assumed. It will be necessary to consider the trade-off between satellite, HF and telephone links.

HF is recognised as having poor reliability, as being subject to interference and as having crowded frequency allocations. The HF links from the student to the teacher are particulary poor. Since there is relatively little investment in these links, other than in transceivers, it could well be cost-effective to spend money making improvements. Discussion with experienced HF communications engineers from the RFDS and Codan Pty Ltd (who supply many of the SOTA HF transceivers) yielded the following advice:

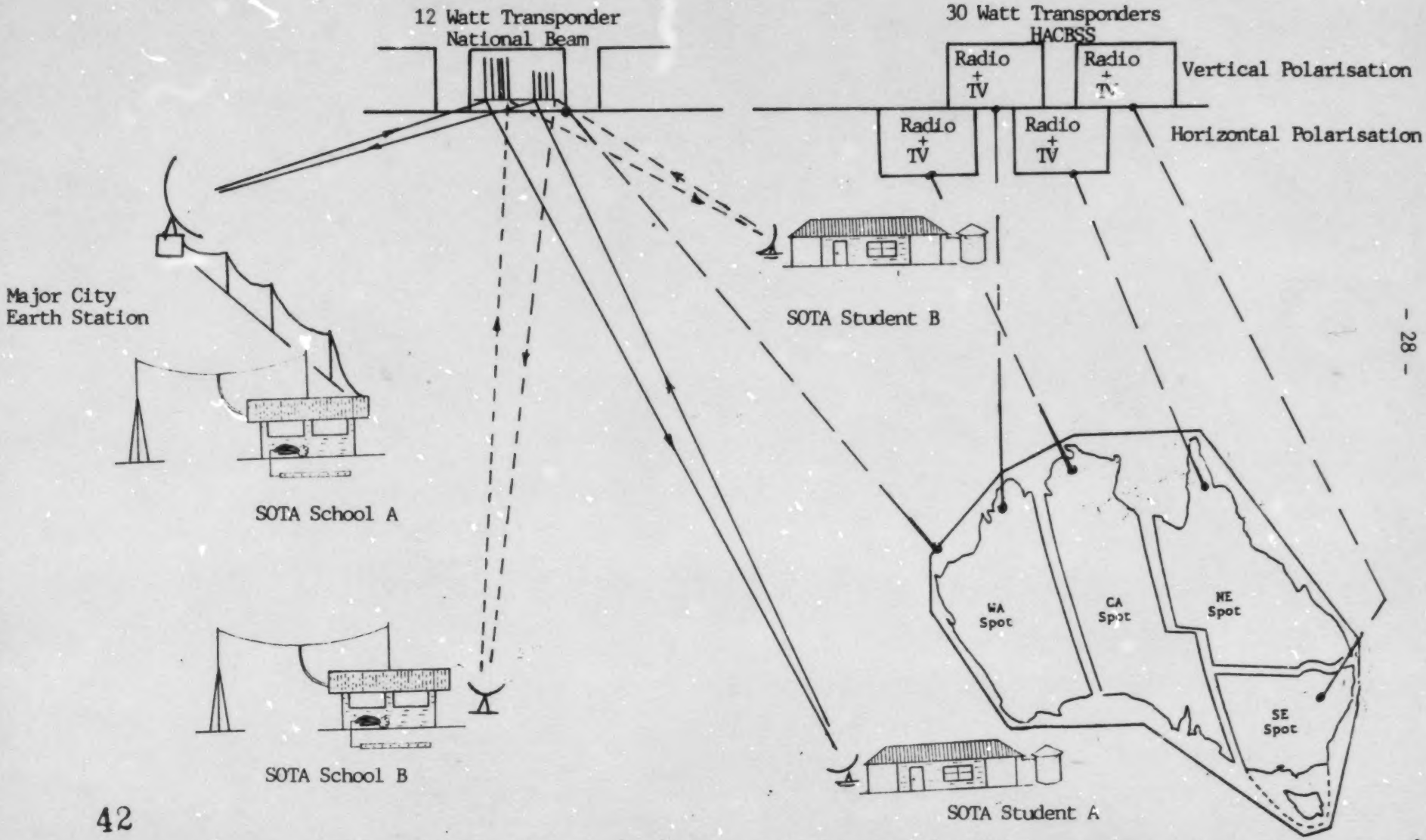


Figure 2.3-8 - Use of 12W Transponder Using National Beams

(a) Antenna installations which are typically made by inexperienced people are a major limitation. The antenna, which for greatest efficiency should be designed for the frequency of operation to provide the best possible match to the transmitter and a high radiation efficiency, should be installed and tested by a trained person to confirm the achievement of design performance.

(b) The transcievers should be operated from mains supplies wherever this is available. Where it is not, a rechargeable battery pack should be provided, preferably not interchangeable with a car battery. The tendency is for the latter to be used in the transceiver after it ceases to work in the car.

(c) Transmit powers of 25 watts should be adequate with a properly designed antenna. Use of 100 watts provides little advantage when path attenuation can change by orders of magnitude within a short time. The delay by perhaps 10 minutes in the loss of a link does not justify the greater power.

(d) Use of speech compression would put more power into the student signal at modest equipment cost. Present licencing regulations and considerations of cost have precluded its use.

From the above, it would seem that the HF student-to-teacher links could be improved almost to the level of the HF teacher-to-student links by selecting a range of antenna designs and employing skilled staff (probably one person per SOTA) to install the appropriate one and to confirm its performance. Power supplies should also be upgraded. Cost estimates to upgrade the student HF links are contained in Part B.

Use of telephones for the student-to-teacher links, which would incorporate teacher-to-student links for those served, is also an alternative. The problems are:

- many locations of SOTA students have very poor quality telephone service, due in some measure to the privately owned and maintained subscriber lines;

- use of the telephone by students makes the telephone unavailable for property or household business for the period of the SOTA class;

- use of the telephone for half hour class periods is an unusual loading of the network.

An average cost estimate of adding a student to a SOTA by means of the telephone network is developed in Part B. It is assumed that satellite as well as terrestrial telephone links would be used and that both could be charged for at STD, community access or INWATS rates.

2.3.4. Optimisation of Transmission Links

The cost summary tables in Part B provide basic costing data useful for the necessary imaginative mixing and matching between the requirements and the most cost effective transmission medium. For example, the analysis assumed that all SOTAs either used major city earth stations for uplinks, with interconnecting terrestrial links, or they used SOTA uplinks. It would be more cost-effective to use major city earth stations where the SOTAs are sufficiently close and SOTA uplinks elsewhere. Similarly, since the cost of telephone links is distance-dependent also, these should be used for the closer-in students and student earth stations for the more distant ones, and where there is no useable telephone. Additionally, student uplink earth stations should be considered for the more permanent longer-term uses and HF transceivers for shorter-term uses such as when the period of participation of students in the SOTA will be for only one or two years or when movement of the family is anticipated. A further mix is SOTA lease of SOTA and student uplinks from an organisation such as AUSSAT rather than ownership, trading off lease costs against the costs of specialized expertise to procure, maintain and operate the earth stations.

3. Enhanced Educational Services

The present SOTAs are an example of distance education which has been operating successfully since a SOTA service was initiated at Alice Springs in 1951. The SOTAs, with the technical support of the RFDS in most cases, have been based on the use of the HF transmission medium. There was no alternative. It is not likely that the SOTAs can develop much further using the HF medium, limited as it is by:

- communications outages;
- interference;
- narrow bandwidth;
- distortion;
- shortage of additional channels.

Due to these limitations, there has been virtually no scope to consider enhanced services which would require:

- reliable communications (>99% in most cases);
- freedom from interference;
- specified channel performance (bandwidth) with the option to increase this at additional cost;
- additional channels.

Educational authorities obviously are best able and have the responsibility to set priorities in the improvement of educational services. Examples of enhanced services which could be provided are set out below. These may suggest others which would be equally or more attractive.

(a) Extended classrooms via one-way television (with individual distant students, or distant schools, monitoring the activities of a live class and contributing via voice links) for regular primary and secondary school subjects, post secondary specialist subjects, trade skills training and adult education;

(b) Full-time audio links for use as in (a) instead of television;

(c) Television and audio links as in (a) and (b) for administrative purposes, teacher training and development and curriculum development;

(d) Television and audio links for the off-line distribution of television and audio programs and hard copy information to the extent that the use of recorders and facsimile equipment is cost effective;

(e) Use of audio or voice links for real-time access to data banks to search for sources of information, obtain specific information and to access teletext services (which are becoming increasingly comprehensive to include services relevant to the business and social interests of the local community);

(f) Capability to dump blocks of data or computer programs into personal or minicomputers at homesteads or in schools to give students access to pages of text, simulation programs (illustrating physical, financial and social phenomena) or simply to teach computer subjects more effectively.

The main point is that it is not physically possible to provide most of the above services over a large geographical area by other than satellite links. The features of a satellite link of distance independence and multi-point distribution permit the addition of a new "subscriber" anywhere in the coverage area at a low incremental cost. Thus the benefits, once a satellite service is initiated, can be very great. The difficulty is that the entry costs are high and that structural changes in the organisation are usually necessary to obtain the full advantages.

4. Recommendations

The present SOTAs are constrained by the limitations of the HF medium which make the conduct of the schedule of classes as presently constituted a challenge for management and the shills of teachers. The scope for improving the school classes and for introducing teaching aids using HF is quite limited. The Loan

Video Program is a recent innovation that shows great promise. It will depend upon the mail service for distribution of program tapes. Satellite communications using the facilities available through AUSSAT Pty Ltd provide an opportunity to greatly improve the existing SOTA and to provide enhanced services to distant students.

While the potential is great, the cost of implementing the transmission service is over an order of magnitude greater than the present cost. To this transmission cost must be added the program software costs associated with an evolutionary change in administration and teaching to take full advantage of the potential of the new delivery medium.

There is no doubt that almost all fixed (as distinct from mobile) communications services will abandon use of HF in favour of a more reliable medium and that satellite communications will be selected whenever the appropriate satellite resources are available and the geographic areas to be covered are large, inhospitable and thinly populated. SOTA and distance education in general are well suited to make use of satellite links. In contrast, the RFDS accepts the limitations of the HF medium for their short messages, do not foresee an augmented service and anticipates a shrinkage of HF service as telephones become more available in remote areas.

Even with the crude analysis of Section 2 and Part B, it appears certain that the most cost effective way of using the ACSS for the basic SOTA services with the option for service enhancements, is to use a 12 watt transponder in the national beam to provide teacher-to-student links to HACBSS type earth stations and some student-to-teacher links with student transmitting earth stations. Because of the present high cost of minor earth stations and the higher skill level which will be needed to install a student transmitting earth station, they cannot be used universally for the student-to-teacher links. Rather, a mix of satellite voice, telephone and HF radio should be used for these links with the appropriate interface and mixing at the teachers' consoles.

The recommendation is therefore to lease a 12 watt transponder with a national beam and use it to provide all the needed SOTA channels for teacher-to-student links and to provide other educational services. The student-to-teacher links should be provided by a mixture of satellite voice, telephone and HF links with the choice based on availability of telephone links, how many years the links will be needed at a particular location and costs. The 12 watt transponder can also be time-shared between use for the SOTAs and use to support audio teleconference links, television or audio links to distant classrooms and multi-point television distribution.

Unfortunately the base of experience on which to argue for such a large change to the renowned SOTAs, with the concomitant financial implications, is limited among telecommunications

specialists (who can advise) and educational authorities (who must make the decisions). It seems therefore that any change should be evolutionary. If at least one of the State educational authorities believes that the expected benefits are worthwhile and makes a commitment to the change, a start towards an improved distance education service could be made. Appendix 4 contains a possible scenario for the evolutionary introduction of satellite communications.

The satellite provides the only practicable facility to deliver educational television to a wide audience. There probably will be the opportunity to share the use of the 30 watt HACBSS transponders for video and audio services either in association with the ABC (in HACBSS 1) or with commercial or public broadcasters (in HACBSS 2). The opportunity is clearly there and could be exploited.

Further, one 12 watt transponder used for SOTA during daytime hours could be used for delivery of educational television to teaching centres and isolated schools during the evenings (transmitting to earth stations having 3.0 to 5.2 m antennas), time shared between educational authorities in different States or, in some instances, being used for topics of interest to all States.

5. Concluding Discussion

The use of the HF medium places a major constraint on the provision of education at a distance either in support of the correspondence schools or to a wider audience. There is consensus among educators and (tele-)communicators that although changes can be made to improve the reliability and the quality of HF links, there is no scope to provide reliability approaching a level of 99%, virtually distortion and interference-free transmission and bandwidths wider than 3 kHz. In fact, it is extremely difficult to obtain even additional 3 kHz channels. The one over riding virtue of use of HF is that it is very very cheap.

Satellite communication, on the other hand, is reliable, distortion and interference-free and can support narrow and wide transmission bandwidths. The major disadvantage is that it is considerably more expensive. A subsidiary disadvantage is that there is no established telecommunications service and considerable work must be done by the educational authorities to define the service and to adapt the inherent flexibility to a particular purpose.

With satellite communications as a new option, the Departments of Education can choose to:

- stay with HF and suffer a SOTA service which will be perceived as being progressively less satisfactory with no opportunity for improvement or the introduction of enhanced services in the rural areas;

- introduce the satellite transmission medium in an evolutionary fashion in those SOTAs where HF transmission problems are most severe and educational needs are sufficiently great, or are likely to reqire expansion;

- introduce satellite communications aggressively to take full advantage of its promise quickly.

If one or more Departments of Education perceive the risks are acceptable to realize the benefits, a minimum program would involve a design study, with educational and telecommunications input, of at least one SOTA (perhaps one in which the use of the HF transmission medium is a severe handicap). This would be followed by a trial service using leased facilities to the greatest extent possible, and the AUSSAT satellites when they become available in 1985, with subsequent expansion to an operational service.

The trial service would involve the following aspects, some of which are suggestions made without prior discussion with the agencies which would be involved:

- lease inter-connections to major city earth stations;

- lease uplink capacity for one teacher audio uplink and one student voice-return channel;

- loan from AUSSAT of a small number of minor earth stations for evaluative purposes;

- loan from DOC of HACBSS receiving earth stations with procurement of hardware to modify them for reception of SOTA teacher audio signals;

- detailed trial planning (along the lines of Appendix 5) organised to allow the evolution to an operational service.

Cost estimates could be developed using the data in this report.

It is hoped that this discussion of the technical options, and projection of the relative transmission costs in Part B will provide the Departments of Education with the basic data on which to decide whether the use of satellite communications at this time for educational purposes is feasible and practicable.

6. Acknowledgement

The authors wish to acknowledge the full co-operation of the educational authorities in providing information and making themselves available to discuss options to provide SOTA and enhanced educational services. The contribution made by Mr John Kitt of Queensland and Dr Norman Bowman of the Northern Territory who accompanied the authors on visits to two SOTAs added greatly to this report.

We would also like to acknowledge the support provided by the Department of Communications for the investigations and for allowing the data, some of which is rather speculative, to be made available in this form for use by the educational authorities in their planning activities.

Reference

AUSSAT Pty Ltd, "AUSSAT, Australia's National Satellite System, - Predicated Communications Performance of The AUSSAT Satellites", 1982.

CALCULATION OF NUMBER OF SOUND PROGRAM CHANNELS OF SPECIFIED QUALITY

Critical factors in the design of the audio channels are the required bandwidth and the acceptable noise level of an otherwise distortion-free link. Should it be as good as FM radio, AM radio or a telephone channel? Another important consideration is the type of earth station. In this section, use of a HACBSS earth station with a 1.5m antenna will be assumed to receive the SOTA audio channel as this will provide the cheapest possible implementation. A HACBSS earth station could be used to receive entertainment television and audio programs when it was not used for SOTA applications.

It is planned that two or three FM radio channels will be transmitted with the HACBSS television in each 30 watt transponder. The earth station will down-convert these radio signals to the 88-108MHz band where they can be demodulated by a commercial FM receiver. This use of the latter receiver establishes the characteristics of the transmission to have a 15kHZ bandwidth and a high signal-to-noise ratio (SNR). This would be a very high quality channel for the teacher-to-student link. If a special demodulator were specified to be attached to the HACBSS earth station to receive a SOTA signal (costing perhaps $10. to $400 in addition to the cost of the basic earth station) a more economical program bandwidth of 8kHz, 5kHz or even 3kHz could be used. The design for these alternatives is outlined in the following.

The details of this appendix are provided for completeness and to show the reader the basis for the estimates of the numbers of channels, and to permit confirmation of these estimates.

15 kHz PROGRAM CHANNELS

		ZONAL BEAM	NATIONAL BEAM
Edge of Coverage EIRP	(dBw)	42.	36.[1]
Output Back-off[7]	(dB)	-2.0	-2.0
Free Space Loss[2]	(dB)	-206.29	-206.29
Atmos Attenuation	(dB)	-0.2	-0.2
Earth Station G/T(see Annex 1)	(dB/K)	16	16
k	(dBw/Hz-K)	228.6	228.6
Multiple Signal C/N_o(downlink)	(dB-Hz)	78.11	72.11

APPENDIX 1

		ZONAL BEAM	NATIONAL BEAM
DEMODULATOR[3,4]			
Compandor		No	No
Full Load TT/N (Weighted)	(dB)	44.3	See Adj Col
Pre-emphasis and noise weighting[5]	(dB)	1.8	
Implementation Loss	(dB)	-1.0	
TT/N at discriminator	(dB)	43.5	
Peak Frequency deviation	(kHz)	100.0	
Receiver Noise Bandwidth[6]	(kHz)	200.0	
Required C/N_o	(dB-Hz)	67.02	67.02
CNR[3]	(dB)	14.0	14.0
Carrier/Intermod Ratio[7]	(dB)	35	35
CNR (downlink)[8]	(dB)	14.1	14.1
C/N_o (downlink/carrier)	(dB-Hz)	67.12	67.12
Number of Carriers	(dB)	11.0	4.99
Number of Carriers		12	3

APPENDIX 1

8 kHz PROGRAM CHANNELS

		ZONAL BEAM		NATIONAL BEAM	
Edge of Coverage EIRP	(dBw)	42.		36[1]	
Output Back-off[7]	(dB)	-2.80	-2.80	-2.0	
Free Space Loss[2]	(dB)	206.29		-206.29	
Atmos Attenuation	(dB)	0.2		0.2	
Earth Station G/T(see Annex 1)	(dB/K)	16		16	
k	(dBw/Hz-K)	228.6		228.6	
Multiple Signal C/N_o(downlink)	(dB-Hz)	77.31	77.31	72.11	
DEMODULATOR[3,4]					
Compandor		No	Yes	No	Yes
Full Load TT/N (Weighted)	(dB)	44.3	40	See Adjacent Columns	
Pre-emphasis and noise weighting[5]	(dB)	-1.9	0		
Implementation Loss	(dB)	-1.0	-1.0		
TT/N at discriminator	(dB)	47.2	41.0		
Peak Frequency Deviation	(kHz)	73.9	45.0		
Receiver Noise Bandwidth	(kHz)	163.8	106.0		
Required C/N_o	(dB-Hz)	65.16	63.27	65.16	63.27
CNR[9]	(dB)	13.0	13.0	13.0	13.0
Carrier/Intermod Ratio[7]	(dB)	>25	19.1	>35	>35
CNR (downlink)[8]	(dB)	13.40	14.34	13.1	13.1
C/N_o (downlink/carrier)	(dB-Hz)	65.56	64.61	65.26	63.37
Number of Carriers	(dB)	11.7	12.7	6.9	8.7
Number of Carriers		14	18	4	7

5 kHz PROGRAM CHANNELS

		ZONAL BEAM		NATIONAL BEAM	
Edge of Coverage EIRP	(dBw)	42		36[1]	
Output Back-off[7]	(dB)	-2.80	-2.81	-2.0	
Free Space Loss[2]	(dB)	206.29		-206.29	
Atmos Attenuation	(dB)	-0.2		-0.2	
Earth Station G/T(see Annex 1)	(dB/K)	16		16	
k	(dBW/Hz-k)	228.6		228.6	
Multiple Signal C/N_o(downlink)	(dB-Hz)	77.31		72.11	
DEMODULATOR[3,4]					
Compandor		No	Yes	No	Yes
				See Adjacent Columns	
Full Load TT/N (Weighted)	(dB)	44.3	40		
Pre-emphasis and noise weighting[5]	(dB)	-3.3	0		
Implementation Loss	(dB)	-1.0	-1.0		
TT/N at discriminator	(dB)	48.6	41.0		
Peak Frequency Deviation	(kHz)	51.6	28.15		
Receiver Noise Bandwidth	(kHz)	113.2	66.30		
Required C/N_o	(dB-Hz)	63.55	61.22	63.55	61.22
CNR[9]	(dB)	13.0	13.0	13.0	13.0
Carrier/Intermod Ratio[4]	(dB)	22.0	19.1	35	35
CNR (downlink)	(dB)	13.68	14.33	13.1	13.1
C/N_o (downlink/carrier)	(dB-Hz)	64.23	62.55	63.65	61.32
Number of Carriers	(dB)	13.1	14.8	8.4	10.8
Number of Carriers		20	29	7	12

APPENDIX 1

TELEPHONE QUALITY CHANNELS

		ZONAL BEAM	NATIONAL BEAM
Edge of Coverage EIRP	(dBW)	42.	36.[1]
Output Back-off[10]	(dB)	-3	-3
Free Space Loss[2]	(dB)	-206.29	-206.29
Atoms Attenuation	(dB)	-.2	-.2
Earth Station G/T[7]	(dB/K)	16	16
k	(dB H2-k)	228.6	228.6
Multiple Signal C/N_o(downlink)	(dB-Hz)	77.11	77.11
C/N_o Demodulator[11]	(dB-Hz)	55.0	
Carrier/Intermod Density[9]	(dB-Hz)	64.0	
C/N_o (downlink/carrier)	(dB)	55.58	55.58
Number of Carriers	(dB)	21.53	15.53
Number of Carriers		142	35

NOTES

1. This level of signal is available at the edge of coverage. A signal level 1-4.7 dB higher could be expected over the interior region of greatest interest for some SOTAs.

2. Calculated at 12.6 GHz for the maximum satellite range. For the minimum range, the free space loss is 205.61 dB giving an additional margin of up to 0.7 dB.

3. The characteristics assumed here are those specified for the HACBSS radio channels. The receiver bandwidth is intentionally chosen to be less than the Carson's Rule bandwidth. The full load test-tone to noise ratio is taken as 44.3 dB, equal to that specified for HACBSS individual reception. When compandors are used, the TT/N ratio is specified to be 40 dB without pre-emphasis or noise weighting. The subjective quality is above 58 dB.

4. The calculation for the required C/N_o per channel is based on the FM equation:

$$TT/N = 3/2 \frac{\Delta f^2}{f_m^3} . \quad WP \quad . \quad IM \quad . \quad C/N_o$$

where TT/N is the full load rms test tone to weighted rms noise ratio

Δf is the peak frequency deviation

f_m is the highest baseband frequency

WP is the pre-emphasis and noise weighting factor (noise weighting in accordance with CCIR Rec 468-3)

IM is the implementation margin, an allowance for non-ideal realization of the demodulator, usually taken as 1 dB for low-cost demodulators

C/N_o is the carrier to noise density ratio at the input to the demodulator

5. For details of the calculation see minute by G Davies dated 13 January 1983. Assumed use of 50us pre-emphasis for HACBSS sound and 75us otherwise.

6. The receiver noise bandwidth is less than the Carson's Rule bandwidth, consistent with the HACBSS design.

7. Exact calculations of the level of intermodulation products for many carriers are very difficult analytically. There is an optimisation between transponder back-off and the level of intermodulation products. For numbers of carriers less than 12, it is possible to choose channels which are free of 3rd order intermodulation products. For larger numbers

these must be allowed for. Simulation programs are typically used to generate specific results. As no tested program is available, results calculated by Telesat Canada for 20 carriers are used here. Other simulations carried out by Chun Loo at CRC of DOC Canada in Ottawa gave a level of 18 dB with 100 carriers. This gives some confidence in using a level of 19.1 dB for 20 to 70 carriers. Values of 25 dB and 22 dB are used for 13 to 20 carriers.

8. An allowance of 0.1 dB is made for uplink CNR and interference.

9. CNR chosen to be 13 dB, a little lower than that used for HACBSS 15 kHz sound programs.

10. Output back-off for 100 carriers.

11. SCPC demodulators developed for telephony services are specified to provide telephone quality at this value of C/N_o (provides noise level 10,000 pW).

EARTH STATION G/T

		1.5 m HACBSS
Ant Gain (12.6 GHz, 55% efficient)	(dB)	43.34
Pointing error allowance	(dB)	-1.0
Ageing Allowance	(dB)	-0.5
Receiver Noise Figure	(dB)	3.5
Receiving System Temp (NF = 3.5 dB)	(K)	370
Receiving System Temp	(dB)	-25.68
Margin for other factors	(dB)	-0.16
G/T	(dB/K)	16.0

APPENDIX 2

LINK ANALYSIS OF STUDENT RESPONSE CHANNEL

The following is a detailed calculation of the number of student response channels that could be accommodated using an antenna diameter of 1.8 m or 2.5 m at the students' homesteads and either a 4 m antenna at the SOTAs or a Major City earth station to receive the signal.

A large number of signals can be accommodated and the calculation serves to indicate the fraction of the transponder power required to provide 18 response channels. Clearly, it would be desirable to accommodate these response channels in the same transponder as the teacher-student links. This will require dividing the transponder into a block for the higher power teacher-student links and a block for the student-teacher links in such a way as to minimise the generation of intermodulation products particularly as these affect the weaker-powered student-teacher downlinks.

		DIAMETER OF STUDENT TRANSMIT ANTENNA	
		1.8m	2.5
Earth Station Tx Power (1 Watt)	(dBw)	0	0
Coupling Losses	(dB)	-1.0	-1.0
Antenna Gain (55% efficiency, 14.4 GHz)	(dB)	46.08	48.94
Atoms. Attenuation	(dB)	-.3	-.3
Maximum Free Space Loss (14.4 GHz)	(dB)	-207.45	-207.45
Satellite G/T	(dB/K)	-2.	-2.
k	(dBw/Hz-K)	228.6	228.6
Uplink C/N_o	(dB-Hz)	63.93	66.79

		Type of Receiving Earth Station			
		4.0 m at SOTA		Major City	
Edge of Coverage EIRP	(dBW)	36.0		36.0	
Output Back-off[2]	(dB)	-3.0		-3.0	
Maximum Free Space Loss[1]	(dB)	-206.29		-206.29	
Atmos. Attenuation	(dB)	-.2		-.2	
Earth Station G/T[3]	(dB/K)	26.5		33	
k	(dBW/Hz-K)	228.6		228.6	
Multiple Signal C/N_o	(dB-Hz)	81.61		88.11	
C/N_o Demodulator	(dB-Hz)	55.0		55.0	
Carrier/Intermod Density[2]	(dB)	61		61	
Diameter of Student Transmit Antenna	(m)	1.8	2.5	1.8	2.5
C/N_o Uplink (see above)	(dB/Hz)	64	66.79	64	66.79
C/N_o Downlink	(dB/Hz)	57.05	56.65	57.05	56.65
Number of Active Carriers	(dB)	24.56	24.96	31.06	31.46
Number of Active Carriers		285	313	1000[4]	1000[4]
Fraction of Transponder Power for 18 channels		6.3%	5.6%	1.8%	1.8%
Total Output Back-off	(dB)	-3			
Total Input Back-off[5]	(dB)	-6			
Relative Back-off per Carrier	(dB)	-24.56	-24.96	31.06	31.46
Back-off per carrier	(dB)	-30.56	-30.56	-37.06	-37.46
Saturated $C/kT = C/N_o$[6]	(dB-Hz)	93.14	93.14	98.14	98.14
		+2.5	+2.5	+2.5	+2.5
		(High Gain)		(Medium Gain)	
Required Uplink C/N_o	(dB-Hz)	62.58 to 65.08	62.18 to 64.68	61.08 to 63.58	60.68 to 63.18
Approximate Uplink Margin (worst gain case)	(dB)	-1.2	2.1	.3	3.6

APPENDIX 2

NOTES

1. Value calculated for the maximum range to a satellite (Satellite at 164°E from an earth station in the SW corner of Australia.)

2. Detailed calculations for a large number of carriers are best done through a simulation program. It is not possible to complete an exact calculation here because of the complex trade-off between output back-off, carrier-to-intermodulation product density ratio and the uplink C/N_o (which becomes a function of the transponder gain or saturating flux density). The value of carrier-to-intermodulation product density used here is one selected from a number of calculations of SCPC operations carried out elsewhere.

3. The G/T value for a 4m antenna with a LNC having a noise figure of 2.5 dB with allowance for mispointing and ageing effects (26.5 dB/K) and the minimum value specified for a major city earth station (33 dB/K).

4. With this number of carriers indicated, factors which have been neglected should be included.

5. This value is between -6 and -8dB depending upon the saturation characteristics of the TWT.

6. The saturating flux density (SFD) is specified as being settable to -80, -85, -90 dBw/m^2 each $\pm$2.5 dB tolerance. The saturated C/kT is given by:

$$C/kT = SFD + G/T + \lambda^2/4 \quad (dB) - k(dB)$$

$$= 103.14, 98.14, 93.14 \text{ dB-Hz } \pm 2.5 \text{ dB}$$

The use of a 1.8 m student antenna is marginally not feasible if the SOTA has a 4 m antenna. The link could be made feasible by:

- taking account of the location of the student earth station rather than assuming the worst-case location;
- reducing the margin for the student-teacher link (ie using a lower value than 55dB for the demoluator C/N_o);
- increasing the diameter of the SOTA antenna to approximately 4.5 m.

This caluclation indicates that only 2-6% of the transponder power is required to support the student-teacher links.

Having shown parameters that make the return link feasible, a very careful calculation is needed to establish the parameters for shared use of a transponder for the links in the two directions.

APPENDIX 3

LINK ANALYSIS FOR TELEVISION DISTRIBUTION USING 12W TRANSPONDERS

The following analysis will be used to determine the size of earth station antenna required to receive a television signal. (See previous appendices for appropriate notes)

		ZONAL BEAM	NATIONAL BEAM
Edge of Coverage EIRP	(dBw)	42	36
Free Space Loss (12.6 GHz)	(dB)	-206.29	
Atmos Attenuation	(dB)	-0.2	
k	(dB/Hz-K)	+228.6	
Downlink (C/N_o - earth station G/T)	(dB-Hz-K)	64.11	58.11
Video Demodulator			
Peak Frequency Deviation (f)	(MHz)	7.1	
Baseband Bandwidth (f_m)	(MHz)	5.0	
Required SNR (p-p video/rms unweighted noise)		30.0	
FM Improvement Factor $(3/2 (\frac{f}{f_m})^2_3)$	(dB)	+62.18	
Conversion rms signal to p-p video	(dB)	-6.12	
Pre-emphasis gain	(dB)	-2.0	
Implementation Margin	(dB)	1.0	
Required C/N_o		85.06	
Receiver Noise Bandwidth	(MHz)	17.5	
Receiver CNR		12.63	
Required Earth Station G/T	(dB/K)	21	27.
Receiving System Temperature (NF of 3.5 dB)	(dB-K)	25.60	25.60
Ageing Allowance	(dB)	0.5	0.5
Pointing Error	(dB)	1.0	1.0
Required antenna gain	(dB)	48.10	54.10
Antenna diameter (55% eff 12.6 GHz)	(m)	2.6	5.2
Antenna diameter (minimum at boresight EIRP = 46 and 40.7 dBw respectively)	(m)	1.6	3.0

SCENARIO FOR THE EVOLUTIONARY INTRODUCTION OF SATELLITE COMMUNICATIONS LINKS IN THE SOTAS

The introduction of a satellite communication services could be managed in the following way. This is put forward as a suggestion to aid in the identification of factors. Other scenarios could be more attractive.

1. Selection of one or more SOTAs for introduction of an improved service. (Perhaps through co-operation and consultation between the State DOEs.)

2. Select a suitable telecommunications consultant to design the system in detail and to manage implementation of the changed cervice (which could be a group from within the Education Department, or AUSSAT, or Telecom or an independent company).

3. Arrange for a suitable technical simulation and demonstration of the planned service using, to the greatest extent possible, the hardware that will be used to provide the service. Arrange for user trials with available terrestrial or experimental satellite facilities.

4. Provide for management visibility for the program and for informing the affected teachers, parents and students.

5. Arrange for the evolutionary changes in administrative arrangements, course content and teacher skills.

6. Arrange for full or part-time lease of a partial 12 watt transponder. The minimum lease would be one teacher-to-student channel and one student-to-teacher channel. (This would be the satellite analog of a HF channel assignment.)

7. Procure the necessary initial number of HACBSS receivers and the special voice channel demodulators interfaced with the receivers.

8. Procure the necessary number of student uplink earth stations.

9. Arrange with AUSSAT for the transmission by a major city earth station of one or more teacher signals and for the necessary terrestrial inter-connection OR arrange for the procurement of a SOTA uplink earth station.

10. Arrange for design of an upgraded HF system and procurement/installation.

11. Discuss basis of student telephone service with Telecom.

12. Plan for the interfacing at the teacher's console of the satellite, telephone and HF links and for an evolutionary transition from HF teacher-to-student links to satellite links.

13. Arrange for co-ordination and exchange of information with all SOTAs which might share the satellite transmission medium.

14. Introduce the service when the satellite becomes available in 1985.

15. Evaluate the service and the cost-effectiveness of the transmission medium with a view to adopting it in all the SOTAs in the States which find this medium to be cost effective.

REPORT PREPARED FOR

THE COMMONWEALTH/STATE ADVISORY COMMITTEE ON THE EDUCATIONAL USE

OF

COMMUNICATIONS TECHNOLOGY

ON

POTENTIAL USE OF THE AUSTRALIAN SATELLITE COMMUNICATIONS SYSTEM FOR SCHOOL OF THE AIR AND ENHANCED EDUCATIONAL SERVICES

PART B

PREPARED BY

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The content of this report is the opinion and views of the authors based on material provided by the members of sub-committee representing the educational authorities. The report is a working document intended to clarify the opportunities for educational applications of the Australian Communications Satellite System (ACSS) for use by members of the Advisory Committee and is not to be taken as representing the opinion or policy of the Department of Communications, the Departments of Education, AUSSAT Pty Ltd or Telecom Australia.

The cost information contained herein was developed by the authors using their own methodology based on capital cost information available in the public domain. AUSSAT Pty Ltd is yet to develop detailed and approved leasing charges for the space and earth segments.

DEPARTMENT OF COMMUNICATIONS

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1. School of the Air - Cost Aspects of Technical Alternatives

In this report, the technical aspects of particular service scenarios are developed in some detail. The costs are more difficult to derive. Where charges are established (as for the use of terrestrial links) or have been given as a guide in public meetings (as for the satellite transponders), these are used. Where the charges are not known, the implementation is hypothetical and charges are therefore even less definite, the approach used here is to develop consistent estimates of costs. These costs are certainly not charges and are intended for use only in the context of this report to examine trade-offs between services by assessing potential benefits of a given service scenario in relation to self-consistent estimates of the transmission costs. The unit of measure of cost should be taken as "counting units", with the symbol $, with dollars convertible to counting units but not the reverse.

If, after assessment, one or two service scenarios are judged to be worthy of development in detail for potential implementation, the desired configuration and the charges will have to be discussed and negotiated in specific detail in consultation and co-operation with AUSSAT and Telecom.

1.1 Use of HACBSS or 12 Watt Transponders for Educational Television

The costs for these form of distribution of educational television are made up of charges for terrestrial interconnection from the source of programs to an uplink earth station, uplink charges, transponder lease charges and downlink charges. Appendix 1 contains a development of relative costs for different links. These can be used to build up relative cost estimates for different specific cases.

a) HACBSS Transponder

For a hypothetical transmission of educational television via a HACBSS transponder channel from a production centre in a major city for 2 hours per day, 5 days per week throughout the school or calendar year, one can estimate the annual transmission charges as being of the order of:

	School Year $'000 pa	Full Year $'000 pa
Terrestrial interconnecting Link (25 km) (Appendix 1, section 3)	16.2	16.2
Uplink 10 hrs/wk x 36 or 52 wks/yr x Uplink Rate of $100 per hr (Appendix 1, section 1)	36.0	52.0
Transponder 10 hrs/wk x 36 or 52 wks/yr x Transponder Rate of $548 per hr (Appendix 1, section 4)	197.3	205.0
	249.5	353.2

The downlinks are provided through HACBSS earth stations which isolated families are assumed to own for the reception of ABC and other entertainment television.

Cost projections in Appendix 1, section 2, for a dedicated uplink facility owned by an educational authority indicate a cost of $52,000-$76,000 pa (compared to the sum of the first two costs above of $52,000-$68,200). This might be attractive if the length of the terrestrial interconnection or the utilisation time per week were longer.

This sets the order of magnitude for the annual transmission costs for a part-time educational television service using a HACBSS transponder to deliver a program into one zone. Estimates of relative costs for other use scenarios could be developed similarily.

b) 12 watt Transponder

An estimate of the costs of the distribution of education television to 25 schools (an arbitrary number) and institutions in a State participating in the use of a 12 watt transponder can be developed as follows:

	School Year $,000 pa	Full Year $,000 pa
Terrestrial interconnecting links (as above)	16.2	16.2
Uplink 10 hrs/wk x 36 or 52 wks/yr (as above)	36.0	52.0
Transponder Assume use of a 12 watt transponder which is leased full-time for SOTA services. It would be available part-time for other services such as television distribution.	Nil	Nil
Downlinks Total of 25 3.0 - 5.2m downlinks at schools and institutions (Appendix 1, section 14)	56	56
	108.2	124.2

1.2 Use of Audio Channels in 12 Watt Transponder for Teacher-to-Student Links in SOTAs

An estimate for the annual transmission costs assuming SOTA use of a full transponder is developed as follows with reference to Appendix 1 for details:

	$'000 pa
Terrestrial links from 12 SOTAs (18 channels) to major city uplinks* (Appendix 1, section 6)	643
Total uplink charge equal to that for one television uplink* since full transponder is used (Appendix 1, section 1)	420
Transponder lease (Appendix 1, section 4)	1,500
Student Downlinks (Appendix 1, section 5)	160
Total	2,723

Pro rated over the 18 SOTA channels, this leads to a cost of about $140,000 pa per SOTA channel. Obviously the cost per channel would be reduced if more channels were accommodated. Some reductions in cost might be achieved by leasing the capacity only during the school day and only during the portion of the year when the schools are in session, but this will depend upon the policy of AUSSAT and the constraints on sub-leasing of capacity.

1.3 Use of Voice Channels in 12 Watt Transponders for Student-to-Teacher Links

The estimated annuallized costs of student return channels can be developed as follows:

Student uplink, for 100 locations (Appendix 1, section 8)	$300,000 pa
Transponder costs - covered by lease of transponder for teacher-to-student links	Nil
Downlink costs using major city earth stations (Appendix 1, section 9)	$ 8,400-$ 25,200 pa
Terrestrial interconnection costs for 18 channels (Appendix 1, section 6)	$643,240 pa
Downlinks through 4 m SOTA earth stations (12 SOTAs) (Appendix 1, section 10)	$ 63,700 pa
Total (with terrestrial interconnections)	$951,640-$968,440 pa
Total (with SOTA downlink earth stations)	$363,700 pa

*An alternative approach is for each SOTA to have a transmitting earth station principally to save the cost of the interconnecting links. Appendix 1, section 7, contains a development of a cost estimate for such an uplink earth station indicating an annual cost of $36,000-$62,000 pa. This would lead to a total annual cost of $456,000-$744,000 for uplinking from 12 SOTAs compared to the estimate of $1,063,000 (the sum of the first two items) derived above.

Clearly there is a large cost advantage in using 4m SOTA earth stations due to the annual cost of the interconnecting links. The estimated cost of the downlink portion of the SOTA earth station could be reduced slightly for those SOTAs which also uplink the teachers' audio signals.

1.4 Upgrading HF Transmission for Student-to-Teacher Links

With repect to upgrading the student-to-teacher HF transmissions, an estimate of the annual cost to improve the student antennas, to provide more reliable power supplies and to maintain the system to a higher standard is developed in Appendix 1, section 11. The annual costs to introduce these improvements are estimated to be $740,000 pa or an average of $62,000 pa per SOTA.

1.5 Telephone Student-to-Teacher Links

With respect to connecting a student to the SOTA by means of the telephone network, an estimate is developed in Appendix 1, section 13, which indicates that the average cost of adding a student to a SOTA by telephone is $2,600 pa. It is assumed that the connection could be by either a terrestrial or a satellite telephone link and that the latter could be charged for at the STD, community access or INMATs rates.

1.6 Cost Summary

It will be useful in concluding this section to summarize the estimates of transmission costs in a manner that can be used for examination of trade-offs for the provision of the SOTA services or an enhanced educational service. It will be assumed that the present enrolment of 2,000 students with 950 subscribers sets or locations is indicative of the ratio of students to sets of 1:2.1. Table 1.4-1 and 1.4-2 contain the summary data.

Table 1.4-1 - Indicative Annual Costs per Location and per Student of Basic Options

Average cost of adding Student to SOTA Using	Per Location	Per Student
HF	$ 156	$ 75
Upgraded HF	$ 775	$ 369
Telephone	$ -	$2,600
Satellite Teacher-to-Student Link	$ 168	$ 80
Satellite Student-to-Teacher Link	$3,000	$1,430

Table 1.4-2 - Estimated Total Annual Costs (12 SOTAs)

Maintenance of Present HF Networks [1] (2%-12% of capital investment)	$ 24,700-$148,000
Installation and maintenance of Upgraded HF Networks (Upgrade plus present Network)	$761,000-$884,000
Telephone Network	Not possible for all students (each student added at the cost of the individual student)
Satellite Teacher-Student Links:	
Using Terrestrial interconnections and Major City earth stations	$2,730,000
Using SOTA Audio channel Uplinks	$2,116,000-$2,404,000
Satellite Student-to-Teacher Links (100 Locations only): [2]	
Using Terrestrial Interconnections and Major City Earth Stations	$ 952,000-$968,000
Using SOTA Voice channel Downlinks	$ 364,000
Educational Television 10 hrs/wk/zone over school year to 4 zones using HACBSS system	$1,000,000
Educational Television 10 hrs/wk/State over school year to 4 States using 12 watt transponder leased for SOTA service	$ 433,000

NOTES

1. 2% provides for maintenance only, 12% provides in addition for depreciation of present transceivers.

2. There would be additional costs for providing the return links via HF or telephone for the balance of the SOTA students.

DEVELOPMENT OF ESTIMATES OF TRANSMISSION COSTS

Development of cost estimates is very risky since the validity depends critically upon the effort and ingenuity that is put into it. To produce a good estimate requires as much effort as that made by the successful bidder on a contract or contender to supply a service. The estimates developed here are compromised by the limited time, data base and expertise available. However, they serve to provide a consistent basis for comparison between options.

While many articles and news items make reference to charges for various types of transmission, there is seldom sufficient detail to determine all the features that are included. Rather than quote a value out of a context, the approach used here is to develop a consistent method of estimation so that comparisons can be made between alternatives on a common basis. While many of the figures and factors that are used in this appendix can be debated, adjustments are very unlikely to change the conclusions. If resources were available, a sensitivity analysis should be made for particular cases.

1. Television Uplink Through Major City Type Earth Station

   Taking note that estimated costs are not charges and the remarks in the above paragraph, the following estimate is attempted:

Capital cost of earth stations*	$34.0m
Buildings and installation (not including basic property or Telemetry and Command function at Sydney and Perth)	$22.0m
	$56.0m
Total cost per earth station (assume dual stations at Sydney, Melbourne and Perth operate with two satellites and dual station at Darwin is for site diversity) - 11 accessing earth stations	$ 5.12m

---

* Based on announced contract for 12 major city earth stations to be installed in each of the capital cities (Canberra, Sydney, Melbourne, Brisbane, Darwin, Perth, Adelaide and Hobart with dual stations to be installed in Sydney, Melbourne, Darwin and Perth) with Mitsubishi Australia Ltd at an estimated cost of $34 m.

Straight line depreciation of earth station over 15 years (6.7% x 34/56m: a provision for the earth stations only, not the buildings)	4.1%pa
Spares at 2% of earth station capital cost (2% x 34/56: as above)	1.2%pa
Interest on depreciated capital @ 20% (20% x 0.5 x 34/56): as above)	6.1%pa
Interest on capital investment in buildings @ 20% (20% x 22/56)	7.9%pa
Operations and Maintenance	10.0%pa
Share of corporate engineering and administration costs plus allowance for operating profit on equity	5.0%pa
	34.3%pa
Estimated annual costs/accessing earth station	$ 1.75m pa

With 11 accessing earth stations, an average of 2.1 full transponder uplinks per earth station would lead to access of 23 transponders from major city earth stations. The balance of 7 transponders (out of a total of 30 transponders in two satellites) would be accessed by the Department of Aviation (4) and commercial television or business users (3). On a basis of equipment cost, the reception equipment costs about half that of transmission equipment. However, all the rest of the equipment, including the antenna and the operations infrastructure, is shared equally. It is therefore reasonable, for the purpose of this report, to divide the cost equally between uplinks and downlinks. This very rough tabulation indicates a cost of $420,000 pa for an uplink. This is in the upper portion of a range which extends down to a charge of $125,000 pa by some operating satellite companies.

Straight line depreciation over 15 years is assumed consistent with professional maintenance and keeping abreast of advances in technology. The percentage values used for spares and operations are justified on the following basis. 2% of the capital cost yields about $680,000 pa which should easily cover replacement of expensive power amplifiers for 2-3 uplinks and other high performance equipment. 10% of the total cost yields about $500,000 pa which should provide for an average of 2-3 operating personnel full time at a station.

Charges for part-time-use could well be on the basis of hours used with a partial-use charge of 100%. This would lead to an uplink charge rate of $100 per hour.

2. Video Uplink Through a Dedicated User-Owned Earth Station

Capital Cost*	$200,000-300,000
Installation	$20,000
	$220,000-320,000
Straight-line depreciation over 15 years	6.7% pa
Spares at 5% of capital cost	5 % pa
Engineering	2 % pa
Operations and Maintenance	10 % pa
	23.7% pa
Estimated annual costs	$52,000-76,000 pa

Straight line depreciation over 15 years is assumed consistent with professional maintenance and advancing technology. 5% of the capital cost yields about $11,000-$16,000 pa which will be marginally adequate for replacement of high power amplifiers and other high performance equipment. 2% for one-time and continuing engineering assistance should be adequate. 10% of the capital cost yields $22,000-$32,000 pa for skilled operations staff time-shared with other video related duties. There is no inclusion for interest on borrowed capital or for profit which are not factors in the activities of the DOEs.

3. Lease of Interconnecting Terrestrial Television Link

For an unprotected link, Telecom Australia charges have been provided verbally as $5525 + $425/km pa. Charges for less than full-time use could be at a reduced rate provided that there are sufficient other users to make the installation economically attractive.

If a 25 km link from a production studio to an AUSSAT earth station is assumed, the upper limit for the charge would be $16,150 pa.

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* Based on procurements made by DOC Canada and Telesat Canada.

4. Lease of Transponder Capacity

AUSSAT has not announced a rate for use of transponders. Also, it is not known whether it will be possible to lease transponders for less than full time or to lease a partial transponder. However, at various times in public meetings a charge of $1.5 m pa and $2.4 m pa, in 1982 prices, for full-time use of a 12 watt and 30 watt transponder respectively has been suggested. For purposes of estimating costs it is realistic to assess the cost of use of a partial transponder on the basis of the fraction of the transmit power used and the cost of part-time-use on the basis of the hours used with a part-time-use charge of 100%. This would lead to a part-time transponder charge rate of $342 and $548 per hour respectively. This brackets an often quoted figure of $400-$500 per hour for itinerant use of 6-10 watt transponders.

5. Downlink to HACBSS Earth Stations

The HACBSS earth stations are expected to be a consumer product which will be available at a cost of approximatley $1,000 each. People in isolated areas could be expected to buy these earth stations to receive the ABC television and radio programs, plus alternative commercial services if these are available.

However, if the educational authorities assumed the responsibility to provide a HACBSS earth station with the addition of a SOTA demodulator, the annual cost could be developed as follows:

Capital cost of 950 earth stations @ $1,000 with demodulator @ $400	$1.33 m
Straight-line depreciation over 10 years	10% pa
Spares and repair of sub-units	2% pa
	12% pa
Estimated annual costs	$160,000 pa

In this case the units are depreciated over 10 years, rather than 15 years, to allow for the stresses of a consumer environment. A factor of 2% is used for spares and repairs to provide for replacement of indoor and outdoor electronic units which fail, with very limited repairs.

6. Lease of Interconnecting Terrestrial Sound Program Channels

Telecom Australia advise that the most widely available facilities for sound programs have a 3 kHz bandwidth. Should 10 kHz be required, the rate is 2x that for 3 kHz channels. For a 3 kHz channel, the full-time annual rate was given verbally as $2,220 + $41 x (Distance - 40 km) up to 1200 km, and $10/km above 1200 km, per annum.

An estimate of the charge for interconnection between the SOTAs and the AUSSAT major city earth stations is developed as follows:

SOTA	Distance from Nearest Major/Capital city Earth Station (km)	Number of Channels	Estimated Cost (pa) (3 kHz program)
WA			
Derby	900 (Darwin)	1	$37,480
Port Hedland	1300	1	50,780
Carnarvon	850	1	35,430
Meekatharra	650	1	27,230
Kalgoorlie	600	1	25,180
NT			
Katherine	300	1	12,880
Alice Springs	1300	2	101,560
QLD			
Charleville	700	4	117,120
Cairns	1400	3	155,340
Mt Isa	1250 (Darwin)	1	50,280
SA			
Port Augusta	300	1	12,880
NSW			
Broken Hill	400 (Adelaide)	1	16,980
		18	$643,140

7. Sound Program Uplink Through Dedicated Earth Stations Owned by the SOTAs

Capital Cost *	$150,000-250,000
Installation	$ 10,000
	$160,000-260,000
Straight-line depreciation over 15 years	6.7 %
Spares at 5% of capital cost	5 % pa
Engineering	2 % pa
Operations and maintenance	10 % pa
	23.7 % pa
Estimated annual cost	$38,000-62,000 pa

An allowance of 5% for spares provides $7,500-$12,500 pa which will be marginally adequate for replacement of the power amplifier and other high performance equipment. Refer to Section 2 of this appendix for the rationale for the other factors.

8. Student Uplink Transmitters

Capital cost - specially adapted earth station in quantities of 100 (see Part A, section 2.3.3). Per unit	$ 15,000
Installation	$ 500-$ 1,000
	$15,500-$16,000
Straight line depreciation over 10 years	10% pa
Engineering	5% pa
Spares and maintenance	4% pa
	19% pa
Estimated annual cost	$2,945-$3,040 pa

The units are depreciated over 10 years to allow for the stresses of a consumer environment as well as of moves to different homesteads. A fairly large allocation of 5% pa is made to engineering because of the more complex nature of two-way operation and SCPC transponder sharing. A factor of 4% is allocated for spares and maintenance to allow for the lower reliability of transmitting units and the greater complexity.

* Based on procurements made by DOC Canada. This cost range covers single to multiple (4-6) channel uplinks.

9. Downlink Through Major City Earth Station

This is very difficult to estimate but as discussed in Section 1 of this Appendix an assignment of costs equally to uplink and downlink is reasonable. This would lead to a cost of $420,000 pa per full transponder downlink. The student return channels use a small fraction of a transponder (2%-6%) and on this basis a pro rata charge for the 18 downlinks would be $8,400-$25,200 pa.

10. Downlink Through SOTA 4 m Receiving Earth Station

The receiving earth station would not be more complicated than a minor earth station less the relatively expensive power amplifier but plus a larger antenna. The cost will therefore be estimated at $25,000.

Capital cost/station	$25,000
Installation	5,000
	$30,000
Straight-line depreciation over 15 years	6.7 % pa
Spares at 5 % of capital cost	5 % pa
Engineering	2 % pa
Operations and maintenance (receive only)	4 % pa
	17.7 % pa
Estimated annual costs/SOTA	$ 5,310 pa
Annual costs 12 SOTAs	$63,700 pa

11. Upgrading of Student HF Transmissions

Capital cost of antenna hardware ($100 per SOTA transceiver/950 transceivers)	$ 95,000
Capital cost of power supplies ($200 per SOTA transceiver/950 transceivers)	$190,000
	$285,000
Straight-line depreciation over 10 years	10 % pa
Engineering	2 % pa
Spares	2 % pa
	14 % pa

Annual cost of hardware	$ 39,900 pa
Annual cost of skilled installer @ $50,000 (including overhead) per SOTA	$600,000 pa
Travelling expenses @ $8,000 per SOTA	$ 96,000 pa
	$735,900 pa

12. Adding a Location to HF Network

Capital cost of transceiver (Codan)	$1,200
Antenna installation	$ 100
	$1,300
Straight-line depreciation over 10 years	10 % pa
Spares and repairs of units	2 %
	12 % pa
Annual cost to add Location	$156 pa

13. Use of Telephone Lines

Telecom Australia have at least three options for charging structures that could be invoked for SOTA application. The STD rates can be applied to any call and are a function of time and distance. For country people, a community centre (not necessarily the location of the SOTA) can be defined and calls to that centre are charged for at the local call rate per each 3 minute period. The SOTA could also request a multi-line INWATs (008) service and pay for calls/line from within a specified area at a specified rate, (e.g. $21 per hour for all calls from within the State of Queensland). There is an installation charge for the latter. The choice from among these or other available charging structures would have to be examined for each particular SOTA. For estimation purposes, the STD rates will be used although these are likely to be a slight over-estimate of the costs.

Telecom Australia publish STD calling charges as a function of the distance. Taking a number of SOTAs (those in WA and NT for which student location maps were obtained) it is estimated that the average distance to students is in the range 165 to 325 km, for which the charge can be derived from STD rates quoted in the telephone directory to be $14.40 per 30 minutes.

As it is not possible to reach all students by telephone, it is not useful to estimate total costs to conduct SOTA classes by telephone. Rather, the average cost of adding a student can be estimated, assuming one 30 minute contact per day to a student at this average distance:

36 teaching weeks x 5 days	=	180 contacts
Annual cost/student	=	$2,600 pa

Telecom Australia is extending current telephone service through the use of a Terrestrial Digital Radio Concentrator System (DRCS) and a Remote Telephone Satellite Service (RTSS). It is assumed that the cost of telephone calls made using these transmission media would not be differentiated.

14. Downlinks for television from 12 watt Transponders

Average Capital cost of 3.0-5.2 m television receive only earth station	$20,000
Installation	$ 1,000
	$21,000
Straight line depreciation over 15 years	6.7% pa
Spares at 2% of capital cost	2 % pa
Maintenance	2 % pa
	10.7% pa
Estimated annual costs	$2,247 pa

For this estimate, depreciation over 15 years is assumed as the earth stations will be located at schools. A fairly high allocation for maintenance is provided due to the higher skill level required to maintain the 5.2m antennas.